ECONOMIC AND CONSERVATION BENEFITS ANALYSIS OF SEDIMENT CONTROL BEST MANAGEMENT PRACTICES IN THE PANOCHE/SILVER CREEK WATERSHED

August 3, 2001

PACKARD FOUNDATION GRANT PROJECT

DRAFT REPORT

Prepared for:

WESTSIDE RESOURCE CONSERVATION DISTRICT

Five Points, CA

Prepared by:

MFG, INC.
consulting scientists and engineers

1165 G Street, Suite E
Arcata, CA 95521
(707) 826-8430
Fax: (707) 826-8437

MFG Project No. 030050

SCHEDULE FOR REVIEW AND SUBMITTAL OF REPORT

August 17, 2001 (Friday) – Comments from CRMP review team to Fred Charles at MFG, Inc., Arcata, CA

August 31, 2001 (Friday) – final report to CRMP and the Packard Foundation

CRMP Review Team
Nettie Drake
Karen Brown
Pam Buford
Bruce Champion
Dave Durham
Chris Eacock
Bruce Eisenman
Krisann Esquivel
Sam Fitton
Louie Garcia

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOS

LIST OF ACRONYMS

Acronym	Description
AUM	Animal Unit Month
BLM	U.S. Bureau of Land Management
BMP	Best Management Practice
CEQA	California Environmental Quality Act
COE	U.S. Army Corps of Engineers
CRMP	Coordinated Resource Management and Planning Group
DFG	California Department of Fish and Game
DWR	Department of Water Resources, State of California
I-5	Interstate-5
NEPA	National Environmental Policy Act
PSCW	Panoche/Silver Creek Watershed
RDM	Residual Dry Matter
RGP	Regional General Permit
RWQCB	Regional Water Quality Control Board
WRCD	Westside Resource Conservation District

LIST OF APPENDICES

ACKNOWLEDGEMENTS

With sincere gratitude, the David and Lucille Packard Foundation – the funding source for the economic and conservation benefits analysis presented in this report – is acknowledged. With the interest and commitment from the Foundation, on-the-ground projects in the Panoche/Silver Creek Watershed (PSCW) are moving from the conceptual stage to actual implementation. From the results of this study, these projects will be focused on maximizing benefits both economically and to the ecosystem (i.e., conservation-focused). As well, projects in other locations that have already been started were identified as data sources to aid future decision-making regarding flood and sediment control actions in the PSCW.

This report was prepared by MFG, Inc., which provided overall project management, sediment need documentation, evaluation of sediment control best management practices, benefits analysis, development of planning and implementation requirements, and development of recommendations. The following MFG personnel were involved in this study: Frederick L. Charles, Maria L. Sonett, Gus Steppen, Brendan Annett, and Jeffrey A. Gilman. The following CRMP members were also involved in various aspects of this study: Nettie R. Drake, Red Martin, Bruce Champion, Bruce Eisenman, Sam Fitton, and Bruce Cotterill. A number of landowners were involved in this study as well, including: Ed Strohn, Charles McCullough, Harry and Jenny Hill, Jeannette and Alta Velasquez, Steve Urritia, Bob Viets. Other stakeholders included: Westlands Water District (George Brunetti), Silver Creek Drainage District (Jeff Bryant), Panoche Water District (Jeff Bryant), Caltrans (Tom Fisher), and Fresno County (Robert Thompson). Data for the City of Mendota was obtained from the 1998 Summers Engineering report regarding flood damages.

1.0 EXECUTIVE SUMMARY

The Panoche/Silver Creek Watershed (PSCW) is a major source of floodwaters and sediment loads to downstream areas during flood events. The overall goal of the PSCW benefits analysis was to provide the information necessary to understand and assess the potential economic and conservation/ecosystem benefits prior to implementing sediment control best management practices (BMPs) in the PSCW. This study considered multiple benefits, including ecosystem health, water quality, flood control, and economic/agricultural productivity, as related to implementation of sediment control BMPs. While this is not a comprehensive benefit-cost analysis, cost estimates for BMP implementation are developed and compared with predicted benefits. This study was conducted according to the following objectives: (1) identify potential landowner and watershed resource needs for erosion and sediment control BMPs; (2) develop BMP implementation scenarios and estimate potential economic and environmental benefits to landowners and downstream interests, including agricultural producers and the City of Mendota; (3) estimate potential conservation benefits from BMP implementation, both locally and in downstream areas, including water and soil quality, rangeland and irrigated cropland resources, and wildlife habitat; and (4) develop information to support ecosystem documentation, as required for the CALFED-funded BMP testing and monitoring program.

The benefits analysis was performed by estimating the ecological and economic value of sediment reduction, erosion control, improved water quality, and reduced flood hazard (reduced peak flows) for the following four BMP implementation scenarios: (1) erosion control structures in high runoff source areas; (2) large flood-control dam near the Panoche-Silver Creek confluence; (3) streambank protection to a significant extent; and (4) vegetative cover improvement in riparian and upland areas. Of these four scenarios, the large flood-control dam does not appear to have benefits that outweigh the costs, and streambank protection benefits appear to be localized in the area of implementation with little positive impact downstream. The flood-control dam was found to have a higher cost than benefit for the range of flood events, from the 2-year to the 100-year peak flow. Therefore, further analysis of a large flood-control dam is not warranted at this time unless construction costs can be decreased or the resulting damage estimates and cost savings increased significantly. The potential benefit from implementing the streambank protection scenario would be almost exclusively limited to the adjacent landowner (whether applied in the upper watershed or the lower watershed) and, therefore, would be most suitable for locations where property or facilities could be lost due to streambank erosion. Because these types of situations are relatively few in the upper watershed, little emphasis should be placed on this type of BMP scenario; large-scale implementation is infeasible. From a flood reduction perspective, little or no benefit would be realized to lower watershed interests from streambank actions in the upper watershed. Also, the geomorphic instability of the existing stream system may be exacerbated by isolated or widespread streambank actions although this determination would require more site-specific information and technical analyses for the reaches in question.

Future analyses and planning for BMP implementation should focus on the other two BMP scenarios – erosion control structures, and grazing management changes. A different set of benefits results from implementing erosion control structures in higher elevations of the upper watershed (upstream of Interstate-5) as compared with changing grazing management in the upper watershed. The erosion control structures would provide a large benefit in flood damage reduction in the lower watershed at relatively low cost and low risk as compared with the large dam scenario. There is strong support for these structures among the landowners interviewed in the upper watershed. Cost savings, in terms of reduced damages to downstream interests, are estimated in the $3 to 4 million dollar range for the 50- and 100-year flood events.

Conversely, grazing management changes would provide a large benefit in terms of increased grazing capacity and land stewardship in general, especially in riparian and upland areas near streams, but would have little to no effect on reducing damages to downstream interests. Nonetheless, implementation of grazing management change is recommended in coordination with the experience of local landowners who may have discovered other techniques to utilize the resource, benefit the ecosystem, and maximize profitability. Grazing management changes could include: (1) limiting season of use; (2) designating target RDM levels; (3) riparian pasture creation; and (4) developing water systems. In addition to potential increases in profitability to the cattle operator, improvement in vegetative cover could also provide the following benefits: (1) dissipation of stream energy associated with high peak flows; (2) filtering sediment, capturing bedload, and aiding in floodplain development; (3) improvement of water retention as well as groundwater recharge; and (4) development of root masses that are capable of stabilizing streambanks against erosional forces. Wildlife habitat would also be improved significantly in the PSCW.

2.0 INTRODUCTION AND OBJECTIVES

The Panoche/Silver Creek Watershed (PSCW), located on the west side of the San Joaquin Valley, drains into the Fresno Slough and, subsequently, the San Joaquin River 35 miles west of Fresno, California. The watershed is approximately 300,000 acres in size and ranges in elevation from 137 feet at the confluence of Panoche Creek with the San Joaquin River to approximately 5,000 feet above sea level on the ridge of the Diablo Range, which is part of the Central Coastal Ranges. A map of the watershed, showing major political and landscape features, is provided as Figure 1. Streams in the PSCW are ephemeral, and flow occurs only in response to runoff events. Runoff from the Panoche and Silver Creek drainage areas has historically created flooding and sedimentation problems for the City of Mendota and surrounding agricultural lands downstream from Interstate-5 (I-5). The most recent period of significant rainfall and runoff was in February 1998 when extensive flooding occurred in areas upstream and downstream of I-5 (referred to herein as the upper and lower watersheds, respectively). In the lower watershed, this flooding results in a large economic impact to agri-business and the community. In addition to the negative impacts from excess water during flooding, the watershed is a principal source of selenium, boron, salts, and other trace elements transported during flooding that subsequently impact soils and groundwater in the Panoche alluvial fan and San Joaquin River.

Soils in the watershed are derived predominantly from marine sediments (sandstones and shales) of the Moreno, Kreyenhagen, and Panoche Formations, and Franciscan Assemblage. These soils support a sparse vegetative cover on most hillsides, with more vegetative cover generally associated with flatter valley floor areas and hillslopes at higher elevations. Large areas of unvegetated soils exist where the soil is thin, particularly on steep slopes and near stream channels. Areas of thin soil also occur over rock containing relatively high concentrations of selenium. The Panoche alluvial fan is the principal source of selenium from the PSCW downstream (via flood and drainage waters) to the Grasslands watershed water bodies and (via flood waters) to the San Joaquin River. Within the PSCW upstream of I-5, approximately 30 percent of the land is managed by the U.S. Bureau of Land Management (BLM), primarily for green-season grazing. Other lands are privately held and used for rangeland grazing or irrigated cropland (just upstream of I-5). Downstream of I-5, lands are used primarily as agricultural cropland.

The PSCW lies within a semi-arid region, with precipitation occurring mainly between November and March. The following approximate average annual precipitation values have been reported for the watershed (DWR, 1981): 15 inches (Idria station) in the southern, higher elevation portion of the watershed (approximately 4,000 feet elevation); 8 to 10 inches (Panoche and Panoche 2SW stations) in Panoche Valley in the central portion of the watershed (1,200 to 1,300 feet elevation); and 7 inches (Mendota Murietta Ranch station) directly southeast of the watershed in the San Joaquin Valley cropland area (approximately 400 feet elevation). Based on this information, the average annual precipitation for the watershed is approximately 8 to 10 inches. Rainfall events yield erosion and the downslope and downstream transport of sediment. During these runoff events, sediment-loading problems occur in downstream agricultural production areas, Mendota urban areas, irrigation water conveyance structures, and streams. High concentrations of selenium are contained within this sediment.

A Coordinated Resource Management and Planning group (CRMP) was formed in 1989 for the PSCW. One CRMP goal is to foster a balance of existing land use practices; another is to develop reasonable management strategies to reduce future water quality impacts associated with flooding. The CRMP consists of residents of Mendota; ranchers and farmers; local resource conservation district personnel; drainage district personnel; water district personnel; representatives of local, state, and federal agencies; and local, state, and federal elected officials. The CRMP identified the need for an erosion/sediment study to identify and quantify point sources and source areas, and to recommend best management practices (BMPs) for reducing sediment loads.

Through the Westside Resource Conservation District (WRCD), the PSCW CRMP has received Clean Water Act 319h and CALFED grants to implement projects to: (1) decrease erosion and sediment transport throughout the watershed, and (2) increase the stability of the rangeland, riparian areas, and stream channels. These projects have been planned and initiated as a result of recommendations made in the Panoche/Silver Creek Watershed Assessment Report (MFG, 1998), referenced herein as the “1998 Sedimentation Study”, in which sediment sources in selected areas upstream of I-5 were evaluated for contributions to sediment delivery downstream from I-5. The 1998 Sedimentation Study was completed through funding from a Clean Water Act 205j grant.

Specific implementation projects are currently being planned and implemented by the CRMP in coordination with local landowners. These existing or potential projects are designed to incorporate one or more sediment control BMPs that include: (1) installing streambank erosion control technologies; (2) providing buffer strips along stream channels through cattle exclusion; (3) developing sustainable rangeland management techniques to enhance wildlife habitat and increase the economic viability of agricultural operations; (4) constructing low-flow crossings to increase stream channel stability; and (5) constructing erosion control structures in upper watershed areas to decrease the magnitudes and velocities of peak runoff in downstream areas.

This report provides an analysis of potential economic and conservation/ecosystem benefits from implementing sediment control BMPs in the PSCW. An evaluation of economic and conservation benefits of potential BMPs for the upper watershed is needed to inform the decision-making process for future implementation of sediment control BMPs. In the CRMP's efforts to improve long-term watershed stewardship, the benefits gained from implementing BMPs must be considered. Therefore, this report considers multiple benefits, including ecosystem health, water quality, flood control, and economic/agricultural productivity, as related to implementation of sediment control BMPs. While this is not a comprehensive benefit-cost analysis, cost estimates for BMP implementation are developed and compared with predicted benefits.

The analysis of benefits addresses the following objectives:

1. Identify potential landowner and watershed resource needs for erosion and sediment control BMPs;

2. Develop BMP implementation scenarios and estimate potential economic and environmental benefits to landowners and downstream interests, including agricultural producers and the City of Mendota;

3. Estimate potential conservation benefits from BMP implementation, both locally and in downstream areas, including water and soil quality, rangeland and irrigated cropland resources, and wildlife habitat; and

4. Develop information to support ecosystem documentation, as required for the CALFED-funded BMP testing and monitoring program.

This report contains the following sections: executive summary (1.0); introduction and objectives (2.0); sediment control needs (3.0); potential sediment control BMPs (4.0); benefits analysis (5.0); planning and implementation requirements (6.0); summary and conclusions (7.0); and references (8.0). Appendices are provided for presentation of BMP conceptual figures (A) and detailed grazing management analyses (B).

3.0 SEDIMENT CONTROL NEEDS

The first component of the economic and conservation benefits analysis involves laying the framework for why sediment control BMPs are needed, both from the perspective of the landowner/land manager and the ecosystem. This information is carried into the benefits analysis (Section 5.0) where flood frequency events are considered. Unless a need for improvement can be demonstrated, there is little purpose in developing methods and directing funds to implement sediment control BMPs. The needs analysis involved landowner questionnaires and visits to a variety of sites in the upper watershed, as well as review of previous studies conducted in the upper and lower watershed areas. Information obtained from these activities is summarized below, and is subdivided into the upper watershed and lower watershed areas; a more detailed map of the upper watershed is provided as Figure 2, which includes identified physiographic features in this area. Land use in the upper watershed is primarily rangeland grazing, whereas the lower watershed supports primarily irrigated agriculture.

As discussed below, needs for erosion and sediment control vary depending on land use and location in the PSCW. In the upper watershed, sediment control needs are directly related to local effects in areas of streambank erosion. Along with adjacent property loss, riparian ecosystems are affected by flooding and erosion. The stability of these areas can be affected by grazing management. In the lower watershed, flooding and accompanying sediment deposition in cropland and populated areas have caused substantial damage. While there are local impacts in property loss due to streambank erosion, large-scale and widespread impacts include sedimentation in irrigation supply canals and on prepared or planted cropland, flood damage in urban streets and residential areas, and flood/sediment damage on roads maintained by Caltrans.

3.1 Upper Watershed

The predominant land use in the upper watershed is rangeland grazing throughout most areas. Other land uses include wildlife habitat, which in many areas is blended with rangeland grazing, particularly in riparian areas and upland areas near streams. The rangeland grazing occurs during the green season (from November to April), with cattle removed in the spring when the grasses senesce or die. The green season is the only period when grazing can occur in un-irrigated areas throughout the Central Coastal Ranges, whereas grazing can occur at other times of the year in regions such as the high-elevation Sierra Nevada.

The largest individual landowner is the BLM, with many of its holdings in the lower elevations of the upper watershed, specifically in the Silver Creek drainage as well as Griswold Hills (Figure 3). The BLM owns approximately one-third of the total land area in the upper watershed. Private landowners operate large ranches in Panoche Valley, Bitterwater Canyon, and the Los Pinos Creek drainage. Other private landowners have smaller holdings and typically reside on or allow grazing by others on their properties. In addition, numerous hunting clubs own land and utilize their holdings seasonally.

Sediment control needs in the upper watershed were documented through landowner contacts and site reviews, as well as during earlier work in the PSCW (MFG, 1998). The discussion of sediment control needs is arranged by: (1) general observations from the 1998 Sedimentation Study and the current study; and (2) landowner site reviews.

3.1.1 General Observations

The 1998 Sedimentation Study was conducted to provide baseline information for making informed decisions related to mitigation of sediment loading in the PSCW. Specific objectives included: (1) evaluation of the rate of soil erosion within the PSCW, and identification of influencing factors such as land use and natural processes; (2) identifying and ranking of high erosion source areas; and (3) assessment of the magnitude of sediment delivery into the lower Panoche Creek alluvial fan (lower watershed). The study found that a principal source of sediment transported to the lower fan area is mainstem streambank and streambed erosion near the confluence of Panoche Creek and Silver Creek ("the confluence"). Relatively minor sources of sediment transport include natural hillslope erosion in the northern Tumey Hills, the hills near Idria, Griswold Canyon, and the hills west and north of the confluence.

The 1998 Sedimentation Study focused on a subset of the entire drainage network. The Panoche Creek channel was evaluated, downstream from the Panoche/Silver Creek confluence, for historical changes since 1924 and geomorphic effects of 1998 floods. Annual sediment yield estimates for the entire PSCW, ranging from 500 to 13,500 tons/square mile per year, were computed and compiled. Based on observations of effects from the 1998 flooding, the following trends were noted: (1) bank erosion was prevalent in the reach of Panoche Creek near the confluence; (2) deposition was prevalent in the reach of Panoche Creek downstream of I-5; (3) bank erosion in reaches downstream of the confluence was localized, occurring mainly on the outside of channel bends; (4) there were short reaches of the channel (several hundred feet long) where the channel migrated tens of feet laterally into the adjacent terrace or alluvial fan deposits in 1998; (5) abundant sediment was deposited upstream of two flow constrictions, the bridge crossing lower Silver Creek and the Fairfax Road bridge; and (6) little hillslope-derived sediment directly entered the channel from slopes downstream of the confluence. Streambank and streambed erosion occurs in other portions of the PSCW, but not to the extent observed near the confluence.

At the time of the 1998 fieldwork, natural hillslope erosion was observed to have been accelerated somewhat by livestock-related denudation of vegetation in some upland and riparian areas of the Silver Creek drainage. However, the transport of sediment from the upland areas to Panoche and Silver Creeks appears to be small in most areas, relative to the magnitude of streambank and streambed erosion contributing to the sediment load of the stream system; this is based on an historical channel change analysis (MFG, 1998). Also, the large amounts of streambank erosion downstream from the confluence appear to be more strongly related to the dynamic geomorphic nature of the stream system, with some influence from land use – primarily related to constraining the channel for cropland use rather than by grazing. Impacts associated with livestock utilization in the lower elevations of the PSCW were noted for the 1997-1998 grazing season. These impacts were concentrated around drainages in both upland and riparian areas of Silver Creek. Herbaceous plant cover was low to absent in some of the drainage bottoms, and impacts to shrub populations were also noted. At the time of the 1998 fieldwork, much of the riparian vegetation along Silver Creek was heavily impacted by livestock congregation, and these impacts contributed to localized bank erosion and disturbance of the native plant community. Management changes (exclusion, shortened season of grazing) have been implemented in these areas since the 1998 Sedimentation Study, and recent observations indicate significant improvement in vegetative cover. Outside the heavily impacted areas, vegetation cover was excellent in 1998, allowing many upland areas to act as vegetated buffers to filter eroded soils and reduce sediment delivery downstream. These findings support the concept that the vegetative condition in riparian areas is important to stability of the system.

As evaluated in the 1998 Sedimentation Study, natural processes have been a primary cause of historical channel change in the overall stream system. Long reaches of active channel erosion and streambank instability were observed, during field work for the current study, in the following areas of the upper watershed: (1) Panoche Creek, both upstream and downstream from its confluence with Silver Creek; (2) Silver Creek; (3) Panoche Creek, from Little Panoche Road downstream to the Panoche low-flow crossing at the east end of Panoche Valley; and (4) Griswold Creek, from its confluence with Panoche Creek upstream into Griswold Canyon. Shorter reaches of active channel erosion also were observed in tributaries upstream of the Silver Creek mainstem. These reaches have experienced dynamic geomorphic change for many years. Some of this change resulted from cattle impacts, but most of the change is inherent in the natural setting and possible residual effects of historical activities including groundwater withdrawal (subsidence) and irrigation dam construction (channel headcutting) (MFG, 1998).

The vegetation community is an important component of the ecosystem in the upper watershed riparian areas. A plant community comprised of native species is believed to be optimum for long-term wildlife habitat requirements, grazing productivity, and stream system stability. Unfortunately, as observed during watershed visits for the current study, exotic salt cedar (tamarisk) has invaded many stream areas in the PSCW (Photo 1). This invasion has occurred through distribution of seed from salt cedar stands via upstream runoff water and, to a lesser extent, by wind transport. Most salt cedar in the PSCW is located along Silver Creek and also along Panoche Creek downstream from the Panoche-Silver Creek confluence to Belmont Avenue (the end of the defined channel in the lower watershed). Some salt cedar removal has been conducted in the lower watershed and on BLM lands in lower Silver Creek. The most effective sequence of removal is to start upstream and work in a downstream direction; this would prevent reseeding of salt cedar by runoff water in areas of previous removal. This type of sequence would require full involvement of upstream private landowners whose properties contain salt cedar stands.

3.1.2 Landowner Site Reviews

Landowners can provide extremely valuable insight into the processes and effects of flooding and erosion throughout the watershed. Input from landowners was a key part of the current study, in order to further define the problems encountered and to document sediment control needs. Visits were made in the following sections of the watershed:

- Moody and Bitterwater Canyons (Strohn property);
- West area of Panoche Valley (McCullough property);
- Panoche Creek, just downstream from Little Panoche Road (Hill property);
- Panoche Creek, just upstream of the Panoche-Griswold Creek confluence (Velasquez property); and
- Panoche Creek, downstream from the Panoche-Griswold Creek confluence at a PG&E gas pipeline crossing (Urritia property).

Each of the landowners had specific issues or opportunities for BMP implementation to discuss. The main concerns were related to: (1) losses to streamside property due to bank erosion and (2) flooding in downstream areas. There was also interest in ecosystem and water quality.

The Strohn and McCullough properties are located in the western portion of the PSCW, at higher elevations where higher annual precipitation (approximately 40 inches in 1998 [Strohn, 2000]) has been measured and correspondingly larger flow rates have originated. The Strohn property area is identified on Figure 2 as Site 7. These high-runoff source areas, especially in Bitterwater and Moody Canyons, contribute significantly to the stages and velocities of flood flows observed downstream. Reduction of peak runoff rates, through temporary detention of flood flows in erosion control structures, is considered to be a viable means to reduce peak stream flow rates and flood stages and to flood less land area east of I-5. One such erosion control structure is located on the McCullough property, and it has been functioning since 1962 as designed by the Soil Conservation Service (now Natural Resources Conservation Service). The structure was designed and installed to reduce peak flow rates and, thus, flooding and erosion of lands immediately downstream on the McCullough property, including hay feeding areas for cattle. This structure provides a prime example of an appropriate setting (geology, drainage area, etc.) and design, as it has operated for approximately 40 years with neither major sediment accumulation nor erosion of the principal spillway, emergency spillway, and crest (Photos 2 through 4). In February 1998, the largest flood flows were handled by this structure since its construction in 1962. Though no damage occurred to the structure itself, flood flows that discharged downstream were large enough to cause some gullying of the channel where the gradient flattens prior to entering Panoche Creek (McCullough, 2001). The erosion control structure is within the non-jurisdictional size limitations, as defined by the California Division of Safety of Dams (DWR, 2001). In summary, both of these landowners in the higher elevations of the upper watershed are aware of the potential impact of runoff from their lands. They are also aware that implementing an erosion control structure BMP on their lands could benefit landowners in the lower watershed with relatively minor benefit to themselves. Nonetheless, they are both interested in contributing their resources to reduce downstream flooding.

The Hill, Velasquez, and Urritia properties each had common issues regarding erosion damage to streambanks during flood flows. Panoche Creek crosses a portion of the Hill property, adjacent to a private dirt ranch road at their southern property boundary, and is actively eroding the 8- to 10-foot high streambank. The section of stream on the Hill property is approximately 0.5-mile long (Site 6 on Figure 2), is currently unfenced and, therefore, is subject to cattle impacts (Photo 5). Fencing separates upstream and downstream landowners from the Hill property (Photo 6). Throughout this stream section, numerous animal burrows and cattle trails are apparent on the steep banks. Vegetation is sparse probably because adequate groundwater is not present, along with other factors including chronic disturbances in the area by cattle and smaller rodent-type animals. As observed during field reviews, animal traffic on streambanks can inhibit riparian vegetation establishment. The key issue at this location is loss of the streambank from erosion during successive flood events; the road is in danger of being eliminated if the streambank continues to erode as it has recently.

Just upstream from the Panoche-Griswold Creek confluence, the Panoche Creek channel is located adjacent to the Velasquez ranch buildings (Site 5 on Figure 2), including an occupied house (Photo 7). The streambank in this area is approximately 12 to 15 feet high and is actively eroding during flood events. This extent of streambank erosion is consistent with reaches upstream and downstream, as well as throughout other areas of the PSCW. Some vegetation has established on the eroded streambank below the house. However, ongoing erosion on portions of the streambank poses a continued threat to the property (Photo 8). The streambank area and riparian zone receive only a minimal amount of cattle and small animal use. The key issue at this location is loss of streambank from erosion during successive flood events. The ranch buildings, including the inhabited house, are in danger of being eliminated at great financial loss to the landowner.

The Urritia property is situated on both sides of the Panoche Creek channel downstream from the Panoche-Griswold Creek confluence. The portion of property of interest is located approximately 0.5-mile south of the main ranch buildings (Site 4 on Figure 2), immediately downstream from a PG&E gas line crossing. The streambank in this area is approximately 25 to 30 feet high and is actively eroding during flood events (Photo 9). Virtually no vegetation is present on the streambank because it is nearly vertical. The key issue at this location is the continual loss of streambank, which is exposing a groundwater well located at the top of the streambank; approximately 5 feet of the top of the well casing is exposed due to this erosion (Photo 10). A stock watering tank is located several feet back from the top of the streambank, and this tank is also in danger of being lost due to erosion. Not only is streambank erosion an issue for the Urritia’s, but also for PG&E as evidenced by a recent repair and protection measure involving rock/geotextile placement immediately upstream of the groundwater well (Photo 11). The soil underlying the rock/geotextile placement in the PG&E repair area closest to the groundwater well has been eroding and no longer provides support for the rock and geotextile.

3.2 Lower Watershed

The lower watershed encompasses the Panoche Creek drainage from I-5 to the San Joaquin River (Figure 1). The predominant land use is irrigated cropland, including crops such as cotton and almond orchards. Various rural roads and the City of Mendota are located in the lower watershed. The California Aqueduct and irrigation supply canals are also located in this area. The need for sediment control measures, as well as related flood control, is readily illustrated through a review of damages to agricultural interests, including farmers and water/drainage providers (Sections 3.2.1 and 3.2.2). Also, the City of Mendota has historically been affected by Panoche Creek flood flows entering its community via Belmont Avenue (from the west). In many respects, documenting (or estimating) the costs of remediation due to property and infrastructure damage after floods can provide the best indication of benefits if these damages are then reduced. However, other less tangible factors, such as sociological effects, can also aid in assessing damage and, therefore, the benefit of future flood controls. Over the last 45 years, there have been at least eight floods exceeding 2,000 cfs, which is near the full channel capacity for some parts of the stream downstream of the California Aqueduct. Although flooding has occurred for many years, recent flood events appear to have caused substantially greater damage (Summers Engineering, 1998), possibly due in part to long-term effects from constraining the channel and from land subsidence due to groundwater withdrawal (MFG, 1998).

The predominant land use in the lower watershed is irrigated cropland agriculture. Other land uses include urban and suburban residential housing and industry, concentrated in the City of Mendota. The basic hydrography of the lower watershed, from I-5 to the Fresno Slough and San Joaquin River, involves flow through the following segments: (1) northeasterly flow of water down Panoche Creek (I-5 to Fairfax Avenue); (2) northerly flow in a constructed channel (from Fairfax Avenue to Belmont Avenue); (3) easterly flow along Belmont Avenue (to the City of Mendota), with significant flood flows spreading over cropland primarily to the north – continuing across these fields and into the San Luis Lift Canals – and diverted in different directions by roadways, levees, and canals; (4) through the City of Mendota in many directions on various streets, depending on placement of temporary dikes, street layout, and other factors; and (5) east-northeasterly into the San Joaquin River (via the Fresno Slough and Mendota Pool). This summary focuses on the damage and sediment/flood control needs for the third and fourth reaches described above – specifically along Belmont Avenue (cropland and water districts) and through Mendota (urban) – because larger flood flows typically overtop the conveyance/channel area in these reaches and, therefore, cause damage to surrounding lands. Historically, flood flows have also broken out of the existing channels in the second reach (downstream of Fairfax Avenue and the California Aqueduct). Farmers in this reach have re-aligned that channel and constructed levees along the sides of the channel to prevent flooding of their lands and, thus, to further focus the flood flows to downstream areas.

3.2.1 Cropland Needs

Agricultural damages account for the highest percentage of all flood damages in the lower watershed (Summers Engineering, 1998). Damages include total crop losses, lost land preparation costs, silt removal and cleanup costs, land re-leveling costs, on-farm irrigation system repairs, delays in crop planting, and reduced crop yields due to sedimentation. Summers Engineering (1998) noted previous estimates of flooded agricultural land areas, associated with 10- and 100-year floods, to be on the order of 6,500 and 30,000 acres, respectively, per event.

The peak flow rate for 1998 was 9,940 cfs, which is roughly a 25-year event (see Table 1). A 1998 survey of agricultural damages estimated that the cost of flood damage was $370/acre (Summers Engineering, 1998). This damage estimate was applied to the flooded area estimate for the hypothetical 100-year event to arrive at a repair cost of $11,100,000.

A threshold of approximately 2,700 cfs exists, below which flood flows in the third reach (along Belmont Avenue) will not flood across the farm fields. This “threshold” was reached in March 2001, during which the maximum flood flow of approximately 2,700 cfs (provisional data) followed the alignment of Belmont Avenue, with some pooling at a location just upstream of the Firebaugh Water District lift canal. Several hundred acres were flooded, but the larger scale flooding did not occur because the flood stages generally did not exceed the “channel” flow capacity. A summary of flood frequency data (Table 1) shows that the 2001 peak flow rate corresponds to a return period between a 5- and 10-year event.

3.2.2 Water District Needs

Westlands Water District’s water supply pipelines and some drainage facilities in the lower watershed used for on-farm re-circulation suffer damages during floods due to siltation. Damages to the Firebaugh Canal Water District’s canal levees, district pumps, electrical panels and telemetry systems occur to a greater or lesser extent depending on the magnitude of the flood flows. The third lift canal is initially overtopped and, subsequently, the second and first lift canals are affected depending on the flood magnitude. Floodwaters that reach the canals eventually drain to the Mendota Pool and degrade its water quality. The Broadview Water District's pumps and motors are also damaged during significant peak flow events.

Water District damage estimates for 1998 flood flows (9,940 cfs), as presented by Summers Engineering (1998), were $75,000 (Westlands), $20,000 (Firebaugh Canal), and $100,000 (Broadview). An estimated $167,000 in total damages to water districts resulted from the 1995 peak flow rate (7,000 cfs) (Bryant, 2001). No damages were incurred as a result of the 2001 peak flow of 2,700 cfs (Bryant, 2001 and Brunetti, 2001). This concurs with the observation that 2,700 cfs is approximately the threshold flow. However, damages have been noted for smaller events; the 1997 5-year peak flow rate (1,800 cfs) resulted in damages to the Panoche Water District totaling approximately $5,600 (Bryant, 2001). These smaller damage amounts are considered negligible for the purposes of this analysis.

3.2.3 Urban Needs

The City of Mendota is usually impacted, to some extent, when Panoche Creek flood flows reach Belmont Avenue. A portion of the floodwaters, which does not flow north from Belmont Avenue (as described for the third reach, above), is conveyed eastward along Belmont Avenue to Mendota. Due to this situation, dirt berms and sandbags are typically placed along and across roadways to direct the flows, if possible, through the southerly portion of Mendota and into the Fresno Slough. Generally, the quantity of floodwater reaching Mendota is directly related to the capacity of the drainage channels on either side of Belmont Avenue. In the past, floodwaters have inundated roughly two-thirds of the city. Primary impacts are to the city's sewer system and to roads including Highways 33 and 180, which are restricted to single-lane traffic when flooding occurs.

During 1998, Mendota not only received floodwaters from Belmont Avenue flows, but some floodwaters backed up on the southwest side of the Firebaugh Canal Water District's third lift canal. This impounded water flowed southeast to the intake canal and eventually flowed through a culvert at Highway 33, flooding a subdivision in northern Mendota. Flooding also affected access to the Mendota High School, which is located southeast of Belmont Avenue and Highway 33. Structural damages were minimized, but damage occurred to a new sewer pump station serving the high school. The city estimates that 1998 flooding damages exceeded $100,000, which is a significant expenditure for repair relative to the city's overall finances. Costs for Caltrans to repair Highways 33 and 180 (Fisher, 2001), as the result of flooding, were $185,000 (1995), $71,000 (1997), and $173,000 (1998).

3.2.4 Total Damages

The expected trend of higher damage costs for larger peak runoff rates generally holds for the lower watershed. Deviations from this trend are likely the result of the dynamic nature of the stream system. Changes in cropping and diking of flood-prone areas, and in the Panoche Creek channel profile and cross section, occur at various frequencies, with each major flood event resulting in further change to the channel plan and profile. Table 2 provides estimates of floodwater and sedimentation total damages in the lower watershed for a series of flood frequency events; the 100-year estimate of $11,100,000 is assumed to represent total damages although it was developed by Summers Engineering (1998) to address only agricultural cropland damages.

For this analysis, a baseline data set of flood damage estimates was compiled from BOR (1981) for peak floods occurring in 1958 and 1969, and from Summers Engineering (1998) for the 1998 peak flood event and for the hypothetical 100-year event. This baseline data set was then used to relate total flood damages to peak flow rate. In addition, flood damage estimates for Highways 33 and 180 for recent years (Fisher, 2001) provide data points for more frequent flood events. Figure 4 shows the linear relationship developed between total damages and return period for existing conditions. This information is used to estimate the reduced damages resulting from decreasing the peak flow rate under the erosion control structures and large flood-control dam BMP implementation scenarios.

4.0 POTENTIAL SEDIMENT CONTROL BMPs

A listing of potential sediment control BMPs is provided in Table 3. Figures illustrating conceptual designs for applicable BMPs are provided in Appendix A. Cost estimates were developed for those BMPs that could be estimated, and also are included in Appendix A. The more viable and potentially more cost-effective sediment control BMPs are discussed in the summary below, followed in Section 5.0 by a benefits analysis for four BMP implementation scenarios. The following sediment control BMPs are summarized:

- Erosion control structures
- Large flood-control dam
- Streambank protection
- Limiting season of use
- Revision of residual dry matter (RDM) levels
- Creating riparian pastures
- Development of watering systems

4.1 Erosion Control Structures

Erosion control structures would include detention facilities designed to temporarily store runoff originating in upper reaches of the upper watershed. These structures would be located only on ephemeral streams, which flow only in response to runoff events. This storage would attenuate peak flow rates and, therefore, decrease the downstream flow velocities, depths, and resulting damage to streams and the surrounding floodplain associated with large rainfall/runoff events. In the upper reaches of the stream system where precipitation is highest, sediment accumulation would be minimal, thus precluding the need for intensive maintenance and requiring only occasional sediment removal. If the structures are placed in lower stream reaches, or in reaches characterized by unstable soils, annual maintenance would be required, probably including removal of accumulated sediment. The small dams would detain runoff water during and immediately after a storm, and then release the runoff downstream at a slower rate over a longer period of time as compared to natural flow. Therefore, the overall volume of flow would be similar to the runoff event under existing conditions, but the maximum flow rate and associated floodwater depth would be decreased. With decreased flow depth in Panoche Creek, the total sediment load would also be expected to decrease because of the decreased height of erosive streambanks in contact with the floodwaters.

This BMP would be effective for reduction of peak flood flow rates and resulting damage to streams and floodplains during major flood events. The relative effectiveness of permanent detention facilities would depend on the size of a dam with respect to the drainage area upstream of each. These detention facilities could be readily implemented with conventional construction methods. Siting them would require a geotechnical investigation. The cost estimate to construct an individual erosion control structure ranges from approximately $190,000 (as estimated in the current study) to $1.6 million (Summers Engineering, 1998); the Summers estimate is based on larger structures that would be detaining flow from larger drainage areas. In addition to the $190,000 estimated construction cost, other costs related to design and permitting could add another 30 percent, thus totaling approximately $250,000 for one erosion control structure. To reduce regulatory requirements for dam construction and, therefore, overall cost, the dam size should be generally limited to the non-jurisdictional dam height of less than 25 feet and storage capacity of less than 50 acre-feet (Department of Water Resources [DWR], 2001). Therefore, each erosion control structure would need to be located in a drainage where its capacity would not be quickly exceeded during more frequent events.

4.2 Large Flood-Control Dam

Construction of a large flood-control dam near the confluence of Panoche and Silver Creeks in the upper watershed could provide storage capacity for a large volume of floodwater and sediment. The large flood-control dam BMP would involve construction of a single dam on Panoche Creek, approximately four miles upstream from the confluence of Panoche and Silver Creeks, with controlled outlet works to discharge a percentage of the flood flow rate. The reduction of peak flow rate would result in potentially decreased streambank erosion, as would construction of permanent upper watershed detention facilities (Section 4.1). However, the main advantage of a single large dam, relative to several smaller upper watershed structures, would be an increased control of flow to reaches downstream from the confluence and to the lower watershed. The reservoir of impounded water would also serve as a sediment trap and settling basin, which could reduce the long-term effectiveness of this BMP unless maintenance is frequent and cost-effective.

It is generally accepted that a large amount of long-term operations and maintenance (O&M) would be required to remove deposited sediments because of the large amount of sediment loading and transport in this reach during flood events. Feasibility evaluation of this BMP would be required to address additional geologic/geotechnical issues of site suitability along with sediment transport/deposition and maintenance implications of the large sediment load. Construction of a single dam structure could be implemented at an estimated cost of $18 million in 1981 dollars (BOR, 1981) to $30 million (Summers Engineering, 1998). Conventional construction equipment could be used for installation, and the dam would be approximately 150 feet high with a top width of 1,050 feet (DWR, 2000). A dam of this size would be within the jurisdictional dam size, as defined by DWR (2001), and would have additional costs associated with meeting regulatory requirements.

4.3 Streambank Protection

Streambank protection can include a combination of BMPs, with selection of the individual BMPs dependent on specific site characteristics. Factors to consider when selecting a streambank protection BMP include geomorphic setting, expected streamflow velocities and stages, streambank height and slope, soil type, adjacent land use, availability of surface water supply for initial irrigation, availability of groundwater supply for natural watering of newly established native plants, availability of plant and construction materials, and availability of qualified personnel to implement the BMPs.

Bank stabilization in critical stream reaches or in livestock access areas could be provided in the form of "hard" treatments such as riprap or gabion baskets. These types of treatments would be integrated with "soft" treatments, such as woody or riparian plantings, that could assist stabilization and enhance aesthetics. Costs for implementation of these "hard" streambank BMPs would be relatively high, and these types of BMPs are not widely adaptable to the changing channel conditions expected in the PSCW. Therefore, "soft" techniques for bank stability enhancement are the focus of the benefits analysis. Construction cost estimates for these "soft" techniques, as well as for revetment installation, are provided in Appendix A. Cost estimates for "hard" treatments are not provided.

"Soft" streambank BMPs could include a range of materials in numerous applications. The following BMPs are considered: geocells, fiberschine, erosion control fabric, brush layering, brush mattresses, pole plantings, post plantings, brush trench, vertical bundles, willow wattles, and pipe-and-wire revetment. It is expected that applications of streambank protection would involve installation of a number of BMPs in the same reach of stream. With the exception of geocells and pipe-and-wire revetment, which would work in conjunction with plant materials, these BMPs rely on natural materials with plants playing a critical role in the overall function. Conceptual figures are presented in Appendix A for each of these BMPs.

Bank stabilization using "soft" streambank BMPs may be an effective method for reducing streambank erosion in many cases. However, the overall effectiveness of these BMPs for reduction of streambank erosion in long stream reaches and in the overall stream system may be limited by the ongoing natural processes (MFG, 1998). Therefore, these BMPs would be best implemented in areas selected with a high potential for loss of land due to streambank erosion. Still, local implementation of these BMPs should also be guided by a geomorphic assessment to avoid initiating or propagating additional streambank erosion. Construction costs associated with implementation of these BMPs, individually, are estimated to range from approximately $540 (pole plantings) to $3,270 (brush mattress) per 100 lineal feet. These estimates assume a bank height of approximately 10 feet; most of these BMPs would perform less adequately in areas of higher streambanks and/or vertical or near-vertical bank slopes. Installation labor costs are higher than material costs except for geocell and fiberschine. Long-term maintenance requirements could be high because of the highly dynamic nature of the channels.

Revetment installation in the stream channel can assist stream recovery by slowing runoff velocities and creating pools where sediment may be deposited. Also, streambank toe stability can be improved through revetment installation along with vegetation planting at the toe. Pipe-and-wire revetment has been installed along several stream reaches in the Arroyo Pasajero watershed, with the intent to decrease velocities at the streambank toe (Photos 12 through 14). This treatment allows planted cottonwood cuttings and other vegetation to establish and provide long-term streambank protection (Viets, 2001).

Revetment can be constructed using pipe posts and wire mesh fence, placed approximately 10 feet out from the streambank toe. Alternatively, natural materials can be used, including brush or trees, although these materials are not expected to hold up as well initially as would a pipe-and-wire revetment. This BMP may provide some local restoration of channel functions; however, overall effectiveness to the stream system may be limited by ongoing natural processes (MFG, 1998). Therefore, this BMP would be best implemented in areas selected with a high potential for loss of land due to large heights of streambank erosion. Conventional construction equipment could be used, and the implementation cost would be approximately $1,200 per 100 lineal feet. Long-term maintenance requirements may be high because of the highly dynamic nature of the channels.

4.4 Limiting Season of Use

Proposed changes in season of use are patterned after BLM–Hollister Field Office grazing management guidelines which limit season of use to approximately five months (December through April). In order to implement this BMP change consistently, BLM also provides guidelines for assessment of appropriate turn-out (putting cattle onto pasture) conditions. These guidelines suggest the use of one or two criteria in the decision-making process: (1) 2 inches of new growth on primary forage plants, and (2) RDM levels in excess of target levels by a minimum of 200 pounds/acre.

Limiting season of use has the potential to improve ecological conditions, and may also improve economic returns for the landowner, as discussed in Appendix B.

4.5 Revision of RDM Levels

Long-term management of annual grasslands for improved ecological conditions and maintenance or improvement of forage production presents a special challenge to the landowner. Without a perennial plant community to act as an indicator of conditions, the manager is limited to the management of RDM levels. Management of RDM levels to achieve optimal protection of soil and plant systems has been shown to result in improved wildlife habitat (Fenten, 2001) and site forage production (Bartolome, 1980). Also, improved vegetative cover is generally held to reduce sediment input to streams and thereby improve water quality.

The use of revised RDM levels must be accompanied by increased site monitoring. Costs associated with the definition of these new target levels are estimated as a total one-time cost of $5,000. Monitoring may be done by landowners, or by a field technician provided by the CRMP if available. The annual cost of monitoring by a technician may be on the order of $10,000 for 10 ranches.

4.6 Creation of Riparian Pastures

Riparian pastures are fenced pasture areas that include a riparian area. The creation of riparian pastures would allow for the recovery of riparian vegetation and bank conditions as discussed in Section 4.3.

Riparian pastures also allow for management of sensitive riparian areas to be separate from upland management decisions. Upland and riparian ecosystems are different, composed of differing soil and plant systems. Therefore, separating them into distinct management units is both logical and beneficial.

Riparian pastures may be utilized with a shortened season of use (shorter than the 5 month recommendation) to protect and enhance soil, plant, and water systems along with wildlife habitat. Careful management of RDM levels in riparian pastures may also create peak production conditions year after year. If these conditions are achieved, the riparian pasture may be used for emergency grazing in drought years, offering an economic benefit and security to the landowner.

4.7 Development of Watering Systems

Watering locations can significantly influence the distribution of livestock over a pasture (Vallentine, 1990).   Adequate numbers of watering locations would spread livestock over the pasture so that all areas of available and accessible forage are utilized, thus reducing congregation in a few areas. Congregation is generally believed to be detrimental to range health, causing soil desiccation through repeated hoof action and by overgrazing.

As a general rule, watering locations should not be located more than one mile apart, and less in steep terrain, so that livestock do not need to walk more than ¼- to ½-mile from forage sources to water (Soil Conservation Service, 1976). Another rule of thumb is to provide one watering location for every 50 to 75 animals. Limiting travel to water reduces energy expenditures, increases weight gains, and also reduces trailing damage to the range (Costello and Driscoll, 1957).

Wildlife can also benefit from the development of livestock water sources. Water tanks should be designed so that wildlife can access water and exit the tanks easily if they fall into the water. Location of salt and water facilities in upland areas also can reduce impacts by drawing livestock away from riparian areas and channel beds.

5.0 BENEFITS ANALYSIS

The benefits analysis was performed by estimating the ecological and economic value of sediment reduction, erosion control, improved water quality, and reduced flood hazard (reduced peak flows). Although numerical values may be placed on certain aspects of these benefits, others are better described qualitatively. Four BMP scenarios were selected to reduce erosion and increase both the productivity and the environmental quality of the watershed ecosystems. These include:

1. *Erosion control structures* in high runoff source areas;
2. *Large flood-control dam* near the Panoche-Silver Creek confluence;
3. *Streambank protection* to a significant extent; and
4. *Vegetative cover improvement* in riparian and upland areas.

Each scenario is evaluated based on one of two approaches, depending on the approach's analytical ability to predict the downstream effects from implementing upstream changes. For example, the first and second scenarios would result in significant hydrologic changes in upstream areas by detaining runoff and reducing peak flow rates, with corresponding changes to downstream landowners and water quality, so these scenarios are evaluated based on differences among flood events of various frequencies. On the other hand, the fourth scenario would involve increasing vegetative cover in upstream areas with some benefits to downstream interests; however, most benefits would be local. Therefore, this fourth scenario is evaluated on a more qualitative basis. The third scenario is evaluated only qualitatively in the context of the effects to the stream system.

5.1 Erosion Control Structures

The first scenario involves application of the in-channel and flow control structure BMPs (detention facilities, or erosion control structures) in the higher sub-drainages (ephemeral streams) of the upper watershed, which is where a large volume of runoff originates because of the higher precipitation relative to the lower watershed. The objectives for implementation of this scenario are to reduce peak flood flow rates, decrease flood stage, and reduce damage to areas downstream of these structures during floods. The lower watershed would be the area benefiting most by reduction of damage. To estimate the effects of this scenario, seven in-channel detention facilities were simulated in different drainages of the upper watershed during the 1998 Sedimentation Study using the HEC-1 hydrologic simulation computer program. The simulation covered the entire upper watershed, upstream of I-5, subdivided into approximately 50 sub-basins. The flow from seven of these sub-basins was assumed to be controlled by erosion control structures. Each detention facility was assumed to impound water to a maximum depth of 20 feet with a maximum impounded surface area of 40 acres.

Relative to the existing condition, the computer model simulation for the erosion control structure scenario showed an approximately 23 percent decrease in peak flow rates (MFG, 1998). For the computed 100-year peak flow rate of 22,310 cfs (Table 1), a decrease of 23 percent would reduce the peak flow rate to 17,180 cfs. This predicted change is viewed as reliable, because the model accounted for spatial variability in rainfall distribution and hydraulic routing of flows in the watershed. The reduction in peak flow rate for more frequent events was estimated, in the current study, by assuming a 50 percent peak flow rate reduction for the 2-year event, and by interpolating between the 100- and 2-year events to estimate percent reductions for the 50-, 25-, 10-, and 5-year events. This was made possible by plotting a line depicting the existing condition on extreme probability plot paper, along with a line depicting reduced peak flow rates between the 100- to 2-year events. The tabular results of this exercise are shown in Table 4.

To estimate the corresponding reduction in sediment load, the sediment rating curve for the I-5 gaging station was applied to the predicted peak flow rates under existing and BMP implementation conditions. The rating curve was developed by North State Resources *et al.* (1999), based on measurements made by the USGS in February 1998, and it was extended, using a power function on log-log plot, to predict sediment loads for the 50- and 100-year events. The estimated total suspended sediment load values under existing and reduced peak flow conditions are presented in Table 4. As shown, significant reductions in sediment load would result from implementation of multiple erosion control structures in the watershed. This substantial reduction is expected because of the decreased height of floodwater and potentially decreased flood flow velocities, thus reducing the potential contributions from streambank erosion and in-channel production of sediment.

As part of the design of erosion control structures, specific potential sites for detention facilities would need to be evaluated for geotechnical characteristics (to address issues which include geology and susceptibility to erosion), size allowances, hydraulics, hydrology, and general feasibility issues, including government regulations, accessibility, and landowner agreements. To reduce costs, the DWR's (2001) dam safety requirements should be reviewed to ensure that each detention facility is within the non-jurisdictional dam size limitations. Also, potential ecological effects of these structures will require evaluation during the design phase. The design should also specify if additional structures are needed to further attenuate flood peak flow rates and where these structures should be located. The priority locations and possible construction phasing of erosion control structures should also be evaluated to optimize implementation and maximize the benefits.

Costs associated with construction of erosion control structures are discussed in Section 3.1. An individual structure would require approximately $250,000 to design and construct. Seven structures would require approximately $1,750,000 to design and construct, although some efficiencies would be expected when building more than one structure in the watershed. The benefits can be estimated using the damage estimates presented in Section 3.2.4 (Table 2), along with reduced flow rate information presented above (Table 4). A summary of the results of this analysis is provided in Table 5, including cost savings (potential benefits) for individual flood events; predicted cost savings are based on the relationship between estimated damages and return period (peak flow rate) presented in Figure 4. Benefits are expected to be substantially increased if a number of flood events are handled with the same erosion control structures. If situated correctly in terms of soils, geology, and land use, the design life of an erosion control structure could be on the order of more than 40 years, as was observed on the McCullough property.

In summary, the following downstream benefits would be realized through implementation of erosion control structures in the upper watershed:

- Overall reduction of peak flow in the mainstem of Panoche Creek;
- Reduction of area of flood inundation and area of sediment deposition on alluvial fan; and
- Potential reduction or avoidance of damages due to overbank flooding on the alluvial fan (i.e. Belmont Avenue floods, irrigation districts impacted, etc.).

The extent of benefits is dependent on the magnitude and reduction of the existing peak flood discharge (2-year, 5-year, etc). Possible characteristics of the extent of benefits for each flood frequency are discussed below:

- *2-year event (50 percent probability of being exceeded in a given year)*: Under existing conditions, flows are generally maintained within the channel and along Belmont Avenue, and there is controlled deposition of sediment on the alluvial fan. Relatively low damage costs are expected under existing and reduced discharge conditions. A minor reduction in the area of flooding may result from this scenario and costs associated with road maintenance to Fresno County and Caltrans potentially reduced or eliminated.

- *5-year event (20 percent probability of exceedance)*: Under existing conditions, flows are generally maintained as for the 2-year event, with a similar minor reduction in flooding expected. Some cost savings could be gained, under the 5-year event, by implementing this BMP scenario.

- *10-year event (10 percent probability of exceedance)*: Under existing conditions, at a peak flow rate of 3,750 cfs. The total damages to agricultural land, water districts, Caltrans, and the City of Mendota would be approximately $1.3 million. Under this BMP implementation scenario, the peak flow rate would be reduced to 2,100 cfs, with predicted total damages of $859,000 – a savings of $441,000. This new reduced peak discharge would also be below the 2,700 cfs flooding threshold (Section 3.2.2), and savings could amount to more than $441,000. This savings is less than the cost associated with design and construction of seven erosion control structures in the upper watershed ($1.75 million).

- *25-year event (4 percent probability of exceedance)*: Under existing conditions, at a peak flow rate of 8,510 cfs, flooding of significant acreage of agricultural land would be expected, with total damages to agricultural land, water districts, Caltrans, and the City of Mendota of approximately $1.9 million. Under the erosion control structure BMP implementation scenario, the peak flow rate would be reduced to 5,400 cfs, with predicted total damages of $1.8 million – a savings of approximately $149,000.

- *50-year event (2 percent probability of exceedance)*: The effects of an event of this magnitude, with reductions due to upper watershed erosion control structures, are expected to be similar to the effects of a 25-year event. At a peak flow rate of 14,130 cfs, under existing conditions, widespread flooding would be expected with total damages of approximately $5.1 million. With erosion control structures implemented, the peak flow rate would be reduced to 9,600 cfs, with predicted total damages of $2.0 million – a savings of approximately $3.1 million. This savings is substantially greater than the cost associated with design and construction of seven erosion control structures in the upper watershed ($1.75 million). Therefore, the benefits outweigh the costs when compared based on total costs and savings.

- *100-year event (1 percent probability of exceedance)*: Although the benefits of erosion control structures would continue at this extreme event, large areas of destruction would result. Therefore, it is difficult to predict the response of the lower watershed resulting from upper watershed changes. Nonetheless, from the current analysis, it is predicted that a savings of approximately $3.7 million may result from implementation of this BMP scenario.

5.2 Large Flood-Control Dam

The second scenario involves construction of a large dam to completely store runoff from the upper watershed for a designated design flood event. Two proposed dam configurations were reviewed for the purpose of this benefits analysis, with the second configuration used for this benefits analysis. A benefit-cost analysis was performed for the first configuration – a proposed embankment structure with outlet works and a downstream floodway located approximately one-quarter mile downstream of the Panoche-

Silver Creek confluence (BOR, 1981). A large dam would be built to provide 9,000 acre-ft of storage providing 7,500 acre-ft of sediment storage (approximately one-half of the 100-yr sediment load). The proposed configuration would completely detain upper watershed flows up to and including the 25-year event, and a spillway would receive flows for floods in excess of the 25-year event. The BOR (1981) report concluded that the proposed project was not economically justified because of the low calculated benefit-cost ratio of 0.39. In addition, it would require the use of a large area of valuable agricultural land for construction making it politically infeasible.

The second configuration, "Panoche Creek Dam Site 2" (DWR, 2000), was reviewed for this benefits analysis. The site commonly referred to as the "Jones site" located on Panoche Creek approximately four miles upstream of the Panoche-Silver Creek confluence could provide a 16,120 acre-ft storage capacity. This dam structure would detain approximately 60 percent of the total runoff volume that normally reaches I-5, providing capacity for the 100-year, 3-day storm volume and the 100-year sediment load. For each return period event analyzed, a projected change in flood frequency was predicted and the corresponding reduction in peak flow rate estimated; for example, the existing 10-year flood event would shift to a 3.3-year flood event under this configuration, which reduces the peak flow rate from 3,750 to 960 cfs, based on the flood frequency vs. peak flow rate relationship plotted on log-probability paper. Predicted damages for the reduced peak flow rates (Table 6) were determined from the information presented in Tables 2.

Construction of a large dam near the Panoche-Silver Creek confluence is expected to provide the same range of benefits as would implementation of erosion control structures discussed above in Section 5.1, although the capacity of a large dam to detain flood flows would be substantially greater. Benefits in terms of streambank erosion and sediment reduction are not addressed by this BMP, nor have ecological benefits been evaluated although these factors would generally benefit from implementation of the large dam BMP. Table 6 provides damage estimates under the second scenario for a series of return periods, and Figure 4 displays the predicted damages vs. return period to show the benefits of the large dam implementation scenario relative to existing conditions and the erosion control structure BMP scenario. Possible characteristics for each flood frequency, as affected by reduced peak discharges, are discussed below:

- 2-year event: Under existing conditions, flows are generally maintained within the channel and along Belmont Avenue and there is controlled deposition on the fan. Under the large dam BMP scenario, lower watershed flood flows could be completely stored by a large dam and, therefore, would have no impact on the lower watershed. Damages are predicted to be avoided ($0), resulting in a savings of approximately $10,000.

- 5-year event: Under existing conditions, flows are generally maintained as for the 2-yr event with some costs incurred in county and Caltrans road maintenance. Under this BMP scenario, the lower watershed flood flows could be detained by a large dam and released at lower rates, thus, avoiding damages and maintenance costs. Damages are predicted to be negligible, providing approximately $700,000 million in cost savings.

- 10-year event: Under existing conditions, at a peak flow rate of 3,750 cfs, damages are predicted to exceed $1.3 million, with extensive damages to agricultural lands, the water districts, Caltrans, and the City of Mendota. Under the large dam BMP scenario, upper watershed flood flows would reduced to a magnitude approximately equal to a 3.3-yr event. Flood flows would be generally maintained within the channel and along Belmont Avenue. Damages of less than $300,000 and a savings of approximately $1.0 million expected.

- 25-year event: Under existing conditions, flooding of a significant acreage of agricultural lands and impacts to the water districts, the City of Mendota, and Caltrans result in total damages in excess of $1.9 million. Under the large dam BMP scenario, lower watershed flood flows would be reduced to the approximately the 10-yr event. Savings of approximately $650,000 are estimated for this return period.

- 50-year event: Under existing conditions, widespread flooding is expected with damages on the order of $5 million. Under this BMP scenario, the return period is reduced to the 15-year event, approximately 5,400 cfs. Damages similar to the 1969 event ($1.8 million) are predicted, with savings of approximately $3.3 million. This savings is less than the cost associated with design and construction of one large dam ($30 million).

- 100-year event: Under the large dam BMP scenario, flood flows would be detained only temporarily, with release of significant flows during peak storage. Downstream flood flows and damages would be similar to those described for the 25-yr event under existing conditions (approximately $1.9 million). Savings of $9.2 million are predicted for this extreme flood event under the large dam BMP scenario. This savings is less than the cost associated with design and construction of one large dam ($30 million), thus, showing costs outweighing the benefits of the large dam BMP scenario. Based on total dollar amounts alone, the benefit-cost ratio for the 100-year event would be approximately 0.31 (9.2/30), which is similar to the 0.39 ratio calculated by BOR (1981).

5.3 Streambank Protection

The third scenario involves implementation of various streambank protection BMPs in the upper watershed. A combination of "soft" streambank BMPs and pipe-and-wire revetment are assumed for this scenario. In some areas, geocells with riparian vegetation plantings could be implemented, while in other areas erosion control fabric and post plantings could be installed. In all areas, pipe-and-wire revetment would be installed to accelerate revegetation of the streambank areas and ensure lower erosion rates while vegetation develops. In areas of these BMP actions, fencing would also be desired to exclude cattle grazing from the areas that are recovering with new plantings and young vegetation.

The total estimated cost for implementing this streambank BMP scenario is approximately $2,820 per 100 lineal feet. This total includes an implementation cost of $1,650 per 100 lineal feet for the "average" streambank BMP, along with pipe-and-wire revetment cost of $1,170 per 100 lineal feet (Appendix A). It is important to note that this estimated cost applies only to streambanks that are approximately 10 feet high or less; higher (or taller) streambanks would be either infeasible or cost prohibitive. For example, the very high streambank observed at the Urritia property would not be amenable to the "average" streambank BMP, but may benefit from a pipe-and-wire revetment along with some cottonwood plantings near the streambank toe although this is uncertain in this situation. As another example, the streambanks in the area of the Panoche-Silver Creek confluence are very high (greater than 30 feet in many reaches) and, therefore, would not be amenable to the "average" streambank BMP. These high streambanks could benefit from a pipe-and-wire revetment in conjunction with plantings.

The potential benefit from implementing this scenario would be almost exclusively limited to the adjacent landowner and, therefore, would be most suitable for locations where property or facilities could be lost due to streambank erosion. Examples include the Urritia property (as qualified above) and Velasquez property. Because these types of situations are relatively few in the upper watershed, little emphasis should be placed on this type of BMP scenario; large-scale implementation is infeasible. From a flood reduction perspective, little or no benefit would be realized to lower watershed interests from these types of actions in the upper watershed. Some benefit in sediment reduction could occur if streambank erosion could be decreased in longer streambank erosion reaches, such as near the Panoche-Silver Creek confluence. However, the feasibility (success) of implementing this scenario is limited by the large height of streambanks in this area. Nonetheless, pipe-and-wire revetment and plantings, in locations such as the confluence area where streambanks are high, could result in less streambank erosion locally.

In the lower watershed, if this type of BMP scenario is implemented where landowners farm near the Panoche Creek channel, some benefits in retaining land by reducing streambank erosion may be realized. Again, these benefits would be localized as for the upper watershed.

5.4 Vegetative Cover Improvement

In the fourth BMP scenario, improvement of vegetative cover in riparian and upland areas would involve implementation of BMPs that mainly reduce the impact of cattle grazing near streams. Vegetative cover condition of the riparian terraces, or riparian areas, is closely linked to the amount of sediment that enters the stream from these areas. Riparian areas are defined as the terrestrial interface between the aquatic environment of the stream/channel system and the upland area. Riparian areas have many important ecological benefits and, if managed well, may also have some important economic benefits for the landowner. Ecological benefits and economic benefits are not mutually exclusive, as discussed below.

Some of the primary riparian ecological benefits attainable through management activities that protect soils and enhance vegetation include:

- Dissipation of stream energy associated with high peak flows;
- Filtering sediment, capturing bedload, and aiding in floodplain development;
- Improvement of water retention as well as groundwater recharge; and
- Development of root masses that are capable of stabilizing streambanks against erosional forces in some areas, although protecting soils and enhancing riparian vegetation would not significantly alter the effects of natural processes which dominate streambank erosion in many parts of the watershed.

Other ecological benefits that are inherent in the attainment of the proper function of the riparian and upland areas include protection and improvement of wildlife habitat, protection of sensitive animal and plant species, and protection and maintenance of productive soil. Clearly, reduction of sediment delivery and improvement of water quality would have direct benefit for downstream landowners and downstream water quality. Improving water retention and groundwater recharge may benefit the upstream landowner if water levels rise in wells and seasonal in-stream flows become perennial flows. Stabilizing banks with vegetation may avert land and property losses in areas adjacent to streams.

But the real challenge here is to value the ecological and economic benefits of desired upland and riparian condition to the upstream landowner because of their investment in implementing management changes (e.g., “process” BMPs). In other words, how does protecting the upland and riparian terrestrial systems benefit the landowner who will be the real investor in the implementation of new BMPs? To lay the groundwork for answering this question, a recent document was reviewed for application to this analysis.

The 1998 BLM document entitled “Rangeland Health Standards and Guidelines for California and Northwestern Nevada, Final EIS outlines four fundamentals of rangeland health. These fundamentals are:

(1) watersheds are properly functioning; (2) ecological processes are in order; (3) water quality complies with State standards; and (4) habitats of protected species are in order. Standards and guidelines are outlined by BLM (1998) and provide a valuable reference for private landowners who wish to work to attain the four fundamentals of rangeland health as stated above. BLM permittees that have implemented management changes, as suggested by BLM range conservationists and wildlife biologists, also provide valuable "hands-on" accounts of their experience in the realities of implementing management changes.

Of the management changes suggested by BLM, four have been identified as potentially applicable to private landowners for the improvement of vegetative cover in riparian and upland areas. The following four grazing management changes are considered for implementation in the upper watershed of the PSCW:

1. Limit the season of use to five months during the region's annual grazing cycle (December through April);
2. Designate target RDM levels that are optimal for protection of plant and soil systems, and that enhance peak standing crop in the following year;
3. Create riparian pastures; and
4. Develop water systems that satisfy requirements for distance between forage and water, and for number of animals per watering location.

These four grazing management changes comprise the fourth scenario, with each implemented to varying degrees according to landowner preference and ability. These grazing management changes are described in Section 4.4 through 4.7. The benefits analysis for the first three components is provided in Section 5.4.1, 5.4.2, and 5.4.3, with additional detail for the first two components provided in Appendix B. The fourth component, water system development, is evaluated as part of the third component, creating riparian pastures.

5.4.1 Limit Season of Use for Riparian and Upland Pastures

Season of use has an important influence on RDM levels and recovery of riparian vegetation (Cotterill, 2001). Timing of grazing pressure at both ends of the growing season is important for optimal site productivity, protection of soil and water resources, and for protection of plant communities that provide wildlife habitat and soil cover. Evaluation of growth and health of key forage plants can be made prior to initiation of grazing. Also, at the end of the grazing season livestock should be removed from the pastures before hot, dry conditions stress both plant and soil systems. The same hot, dry conditions will cause grasses to dry out and lose much of their nutritional value. This requires livestock to search for better forage that may be farther from water and they may consequently lose weight (BLM, 1998). Traditionally, this is also the period of time that the riparian areas are more frequently sought out, as livestock seek cooler temperatures and greener grasses in wetter areas. With the fencing of riparian areas, these resources will no longer be freely available to livestock; removing them prior to the hot, dry month at the end of the grazing season may minimize weight loss as well as protect riparian areas. As detailed in the cost analysis in Appendix B, if cattle are kept on the land for one month too long (under hot, dry conditions), the potential losses to the operator could be on the order of $9,000 for an example herd of 200 steers, assuming weight loss of 50 pounds each. Therefore, early removal of livestock (limiting the grazing season) is an example of how ecological and economic benefits both can be achieved.

5.4.2 Designating Target RDM for Riparian and Upland Pastures

Protection and enhancement of riparian and upland resources, by designating target RDM levels, may also increase peak standing crop that, in turn, can result in greater livestock carrying capacity. When adequate levels of RDM are left on the range, peak standing crop in the next year increases, as documented by Bartolome (1980) and observed by other range scientists. Bartolome (1980) also found that sites located in xeric (less than 10 inches mean annual precipitation) areas did not respond with equivalent increases in standing crop in response to added mulch as did other plots located in more mesic (25 to 40 inches mean annual precipitation) climates. Responses in mesic sites were immediate – increases were seen in the following growing season. Local field observations indicate, however, that there is a strong positive relationship between mulch levels and the next year's standing crop, even in xeric sites located in the PSCW (Cotterill, 2001). Therefore, a positive linear correlation between the increase in forage and the added amount of mulch is assumed in both the mesic and the xeric sites.

In one type of valuation of economic benefit, increases in standing crop (the weight of unharvested forage standing per unit area) are translated directly into potential increases in animal unit months (AUMs). As detailed in Appendix B, the AUM is a quantitative measure of carrying capacity and is calculated as 750 pounds of air dry forage (Vallentine, 1990). If increasing RDM levels are linear to increases in AUMs, an RDM increase to 1,000 to 1,200 pounds per acre (Hollister-BLM recommended levels) could result in projected increases in standing crop for a 100-acre pasture of approximately 85 AUMs (see Appendix B), or 0.85 AUM/ac.

Based on USDA beef cattle prices (USDA, 2001) from 1991 to 2001, at an average of $91.26/cwt, and assuming a rate gain of one pound/day (Vallentine, 1990), a 350-lb calf grazing for five months would gain 150 pounds, bringing a market price of $456; his 150-pound weight increase is valued at $137. Therefore, the 5 AUMs needed to gain that weight are also worth the increase in sale price ($137). If the grazing costs are $3.52/AUM (BLM, 1998), then the 150 pounds of weight gain (for 5 AUMs) will cost the operator $17.60, and the difference of $119 (= $137 – $17.60) can be translated to $23.85/AUM in profit to the operator. For a 100-acre pasture, an increase in carrying capacity of 85 AUMs would result in potential profit increases of $2027.25 (or, $20.27/ac) if the additional carrying capacity is fully utilized.

Pastures within and near riaparian areas that have been managed to optimize forage productivity can also be of value to the rancher in drought conditions. While in the perennial grassland systems, continued stocking at normal or higher levels is probably the greatest cause of range deterioration (Vallentine, 1990), in the annual grassland system it may be possible to utilize these areas at higher levels for one season while still targeting an acceptable level of RDM. The season of emergency grazing should, however, be followed by a season of lower level utilization, or by deferment. Both upland and riparian pastures will also respond to increased levels of RDM. Additional information on benefits of target RDM for riparian and upland pastures is presented in Appendix B.

5.4.3 Creating Riparian Pastures and Related Measures

Creating riparian pastures, short-term deferment of grazing, restoration of riparian vegetation, and development of cattle watering systems also can improve the ecosystem and economic bounty of riparian areas. Benefits of fencing riparian pastures logically include reestablishment of riparian vegetation. Riparian vegetation will have many ecological benefits and will reduce sediment delivery from these areas, improve water quality, and provide some minor reduction in peak flows downstream. In stream reaches where streambanks are shorter and not as steeply sloped, riparian vegetation will also protect banks from erosion (Meehan, 1996). Healthy stands of riparian vegetation also provide important habitat for birds and small mammals species. Implementation of these BMPs would improve wildlife habitat areas throughout the watershed. Maintaining the processes of soil and plant community development would provide the mechanisms necessary for rangeland communities and, thus, allow wildlife habitat areas to exhibit resilience and resistance to extreme events such as drought, wildfire, or rainstorms (NRC, 1994).

Fencing of riparian pasture will allow management of these areas to be independent of other (i.e., upland) management decisions, and will allow for complete deferment during a recovery period. A potential recovery period from the year 2001 through 2003 has been identified for purposes of this discussion. This period would allow planted and natural riparian vegetation to become established without possibility of consumption or trampling by livestock (Odion *et al.*, 1990; Armour *et al.*, 1994; Elmore and Kaufman, 1994). Reinstatement of grazing would occur three years after initiation (e.g., in the year 2004). Careful monitoring to fine-tune stocking rates and seasons of use would be required after reinstatement.

Restoration of riparian vegetation will not be largely successful unless grazing is deferred for a period of time sufficient for the establishment of riparian plants. It has been assumed, if adequate water is available, that a minimum of three years would be required for recovery of riparian vegetation (willows, cottonwoods, and herbaceous rushes and sedges). Table 7 provides a brief benefit-cost analysis for the restoration of a one-half mile reach of stream in the PSCW that is also fenced in a 100-acre riparian pasture. This restoration includes several restoration techniques, including cottonwood and willow planting, placement of willow wattles, and minor streambank reconfiguration. Over a 20-year period, the benefit-cost ratio would be 1.3 ($116,127/87,997).

5.4.4 Potential Benefits

The annualized benefits analysis for vegetative cover improvement assumes a 20-year period, with an initial 3-year period of change in RDM and other factors. Four management aspects comprise this fourth scenario at varying degrees of implementation, as analyzed herein, with each providing some level of improvement largely in the riparian areas and, to a lesser extent, in the upland areas. While the focus of this part of the benefits analysis deals with improvement in vegetative cover for grazing and cattle carrying capacity, additional benefits would be realized including: (1) dissipation of stream energy associated with high peak flows; (2) filtering sediment, capturing bedload, and aiding in floodplain development; (3) improvement of water retention as well as groundwater recharge; and (4) development of root masses that are capable of stabilizing streambanks against erosional forces. Wildlife habitat would also be improved significantly in the PSCW. However, these non-grazing benefits are not quantified in this analysis because of their dispersed nature on varying landscapes (i.e., somewhat minor actions occurring over a potentially large area).

In summary, four components of this scenario are evaluated in this benefits analysis: (1) limiting season of use; (2) designating target RDM levels; (3) riparian pasture creation; and (4) developing water systems. The third and fourth components are evaluated together. Benefits associated with each, in term of dollar value, should be viewed independently and not additively, as the operators would be expected to implement the components individually as best suited. Reducing the season of use (from six to five months) could result in approximately $9,000 (for 200 steers), or $45/steer, in cost savings to the cattle operator, assuming 50 pounds of weight loss per steer [MARIA - check this with BLM] in the sixth month due to hot and dry conditions. Also, early removal of livestock would improve RDM and standing crop and, thus, improve vegetative conditions for the start of the next grazing season, as well as for enhancing wildlife habitat in riparian areas and upland areas near streams. While specific monetary benefits cannot be readily assigned to these components, they are expected to: (1) improve water quality; (2) protect streambanks from erosion in areas of mild streambank heights and slopes; (3) provide important habitat for bird and small mammal species; (4) provide increased resilience and resistance of wildlife habitat areas to extreme events such as drought, wildfire, or rainstorms; (5) reduce soil desiccation and compaction; and (6) reduce cattle energy consumption.

Establishing target RDM levels, for a 100-acre pasture, could result in an increase in carrying capacity of 85 AUMs, which translates to potential profit increases of $2,027 (or, $20.27/ac) if the additional carrying capacity is fully utilized. Riparian pastures that have been managed to optimize forage productivity can also be of value to the rancher in drought conditions. Again, not only would the cattle operator benefit in terms of increased profits, but wildlife habitat would be enhanced by the additional RDM and standing crop, especially in riparian areas and upland areas near streams.

6.0 PLANNING AND IMPLEMENTATION REQUIREMENTS

The discussion below provides a descriptive summary of the various activities that are part of the planning process and BMP implementation process, presented in Sections 6.1 and 6.2, respectively. As part of the benefits analysis, several potential streambank protection BMP implementation sites were identified both upstream and downstream of I-5. Erosion control structures were also identified as potential BMPs, but they require more investigation prior to design and implementation. A total of six streambank BMP sites are identified on Figure 2, with the seventh area identified for erosion control structures in higher elevations of the upper watershed. These sites are shown on Figure 4 and are discussed in Section 6.3.

6.1 Planning Requirements

As discussed below, activities that would be considered part of the planning phase include: analysis of the site, obtaining landowner access agreements, identification of environmental permit requirements, and design of the BMP.

6.1.1 Analysis of the Site

Site analysis is required as the first step in the planning phase because each site will have unique implementation parameters and limitations, which will directly impact the specific BMP selected in the context of the overall setting. The entire stream and/or ecological system should be evaluated – not just the part of the system where a BMP is considered. First, the objectives for an individual site must be established in coordination with the landowner. Technical experts that should be involved in this activity should be selected, depending on setting and type of BMP to be considered. For example, a streambank protection BMP should involve analysis of short- and long-term channel change (plan, profile, and cross section) upstream, downstream, and within the reach of BMP implementation.

Site parameters, both for documentation of existing conditions and development of design parameters. For the streambank example, channel and streambank velocities should be estimated. Potential downstream effects and benefits to local and downstream parties should be assessed as part of the site analysis. A geomorphic evaluation should be conducted to ensure that streambank actions are consistent with the overall setting and that these actions will not result in negative stream stability effects in downstream areas. In many reaches, the recommendation may be to avoid streambank actions because of limiting site and stream system geomorphologic conditions. Implementation of “soft” streambank BMPs should reduce the risk of failure and negative geomorphic effects in most cases where conditions do not exclude these types of BMPs.

6.1.2 Obtaining Landowner Access Agreements

Written permission must be granted from the involved landowners to gain access to their properties for BMP implementation. The landowner commitment to cost-share or matching (in-kind) funds, if grant dollars are obtained, may be part of the landowner agreement. The written landowner access agreement will serve as a part of the overall contract between the landowner and parties assisting with or directing the work. Access will be required for BMP implementation as well as future monitoring activities. The written agreement will delineate responsibilities of parties involved including implementation, monitoring, etc.

6.1.3 Identification of Environmental Permit Requirements

The environmental permits required will depend on the type of BMP to be implemented. In general, vegetation improvement and grazing management BMPs implemented in upland and riparian areas will not require environmental permitting, except for specific county requirements related to movement of significant volumes of fill (e.g., 50 cubic yards or more), application of pesticides/herbicides, or introduction of restricted plants. If projects are located on Federal lands and/or Federal resources are used for implementation, then National Environmental Policy Act (NEPA) requirements may also apply. County and NEPA requirements are not discussed further in this section, but they should be addressed if applicable actions are proposed. The focus of the following discussion is on streambank and streambed BMPs because of the permitting requirements associated with these actions. Environmental compliance would include, but may not be limited to: California Department of Fish and Game (DFG) 1600 series requirements; California Environmental Quality Act (CEQA) requirements; Army Corps of Engineers (COE) “404” requirements; and 401 certification requirements from the Regional Water Quality Control Board (RWQCB). Data collection and information compilation, along with a project plan, are required for review and approval of permit applications by agencies. Typically, agencies will provide checklists to guide the applicant through this process.

A stream alteration agreement will be needed for BMPs occurring in stream channels or banks, in accordance with California Fish and Game Code Section 1603 ("1603 permit"). Section 1601 of the Fish and Game Code requires notification to DFG before beginning a construction project that will: (1) divert, obstruct, or change the natural flow or the bed, channel, or bank of any river, stream or lake; (2) use materials from a streambed; or (3) result in the disposal or deposition of debris, waste, or other material containing crumbled, flaked, or ground pavement where it can pass into any river, stream, or lake. Provisions of the 1603 permit, addressing conditions during construction, would include protection of plants and wildlife, flagging/fencing of work areas, minimizing disturbance or removal of vegetation, vehicle access restrictions, erosion control, and other site-specific actions. DFG is required to comply with the CEQA prior to issuing agreements (i.e., 1603 permits). CEQA would require review of biological resources via the California Natural Diversity Database and review of cultural resources via the California Historical Resource Information System; the San Joaquin Valley Archeological Information System (Bakersfield) would apply to Fresno County sites and the Northwest Information Center (Rohnert Park) would apply to San Benito sites. Other documentation requirements under CEQA would include: a project map; an up-to-date list of sensitive species; and determination of effects to species. A CEQA Mitigation Monitoring and Reporting Program will be required for implementation of the actions under the 1603 permit.

A COE "404 permit" would require specifications for the projects that will include work in a channel such as revetments, bioengineered bank stabilization, in-channel plantings, or low-water crossings. A Regional General Permit (RGP) for sediment reduction could be granted, and would include approved types of projects to be implemented in the project area over a specified period of time. Annual reports to the COE would be required. If a COE 404 permit is required, then a 401 certification also would be required from the RWQCB.

6.1.4 Design of the BMP

The type of design required for a particular BMP will depend on available engineering standards and practices for that BMP. For example, design of a large dam would require a variety of engineering analyses to assess soil properties, hydrology, earthworks, hydraulic structures, and other related components of the system. This type of design would need to be conducted under the direction of a California registered engineer. A set of detailed engineering drawings and technical specifications would be developed to communicate the essential nature of the design to the construction contractor and on-site quality control supervisor. Essentially, a complete design package will be detailed to an extent to communicate abstract ideas into real, measurable project parameters. While a detailed engineering design would be required for a structure such as a dam (or riprap streambank protection BMP), BMPs such as animal exclusion fencing or vegetation plantings would not require engineering analysis and design unless they are integrated into an engineered structure.

6.2 Implementation Requirements

Activities that would be considered part of the implementation phase include: construction and monitoring during construction, and monitoring/documentation of environmental parameters after construction of the BMP. For a BMP not specifically requiring construction, such as a change in grazing management, only monitoring and documentation after implementation would be required.

6.2.1 Construction and Monitoring during Construction

Contractor selection is required for BMP implementation involving construction activities. As noted above, this discussion applies only to those BMPs for which structural measures (e.g., dam construction, rock riprap banks, etc.) would be part of the implementation phase. The design package, that would include engineering drawings and technical specifications, should be used to obtain competitive bids from contractors familiar with implementation of the BMPs selected. Competitive bids may not be needed if a contractor with unique knowledge and history with the site and experience constructing the selected BMPs has already been identified. Nonetheless, the selected contractor must be qualified and the estimated cost must be within the total allowed construction budget for the project.

A number of construction aspects must be addressed while planning the construction sequence and timing. First, the time of year must be considered. In most cases, construction work should be completed during the dry season (between May and October), suspended during the wet season (November through April), and restarted again when the dry season arrives again. It is desirable to complete construction within one dry season to, therefore, avoid flood or erosion damage to partially completed structures. The staging and phasing of various construction activities should be planned and coordinated to reduce periods of inactivity.

Site documentation should address: (1) existing conditions; (2) conditions during construction; and (3) final conditions. A daily field log should be maintained to record pertinent site information that could affect the short- and long-term performance of the BMP. Communications records also should be maintained. Documentation and acceptance of final conditions should be completed at the end of construction, and a final as-built report and data submitted to the landowner and other parties involved in the BMP implementation.

6.2.2 Monitoring and Documentation during Implementation of the BMP

Monitoring and documentation of site characteristics and indicator parameters should be conducted for the first several years after construction of the BMP. This phase is termed the "implementation" period for purposes of this discussion. Typical monitoring and documentation plans should address: (1) location, (2) timing, (3) methods, and (4) data evaluation of monitoring activities. In some cases, monitoring can be performed under the guidance of an approved Quality Assurance Project Plan, if the BMP is part of a larger program such as CALFED.

Locations selected for monitoring are critical for accurate and reliable evaluations of the success of BMP implementation. The same locations selected for monitoring of existing (pre-BMP) and final (at conclusion of construction) conditions should also be selected for monitoring during implementation (after constructing or initiating the BMP). The timing of monitoring and documentation should be consistent and relevant to the type of BMP implemented. For example, a flood or erosion structure should be monitored after each major flood event or at regular intervals during the winter season. These types of BMPs also should be monitored early in the dry season to assess for any corrective or repair actions that should be completed prior to the next winter season.

The monitoring methods should provide meaningful data at the accuracy required for making reliable assessments regarding the success of the BMP. For many of sediment and erosion control BMPs, photograph monitoring (photo-monitoring) is the extent of intensity required. Streambank BMPs should typically be monitored by a combination of photo-monitoring and surveyed stream cross-section and profile data collection. Monitoring methods should be selected to aid in decision-making for future actions such as implementation of similar BMPs and correction of existing BMPs; a link should be shown between monitoring data and adaptive management while planning and selecting monitoring methods. Documentation and reporting requirements should also be specified, along with examples of how the monitoring data can be evaluated.

6.3 BMP Testing and Monitoring Sites and Procedures

Implementation sites and BMP project locations are shown on Figure 2. BMP project sites 1 through 6 were identified for implementation in the PSCW over the next several years. Project site 7 has been identified for further evaluation for possible erosion control structures, and is evaluated in terms of benefits and cost in Section 5.1 of this report (funded by the Packard Foundation). Other projects, including grazing management change BMPs, will be encouraged over the next several years but are not currently scheduled on the same time line as the seven discussed below. Project sites 1 through 3, in the lower watershed, are implemented as part of the current 319h implementation program. Project sites 4 through 6, in the upper watershed, are planned for implementation as part of the CALFED program and were evaluated as part of the current study (funded by the Packard Foundation). The BMP testing and monitoring (i.e., project) sites are described in this section. Sites 1 through 6 are scheduled for geomorphic monitoring as part of the CALFED program.

The three lower watershed sites include: Site 1 – low-flow crossing (North Avenue); Site 2 – pipe-and-wire revetment plus vegetation (Anderson-Clayton property); and Site 3 – pipe-and-wire revetment plus vegetation (Souza property). Sites 2 and 3 are in the initial phases of implementation, and Site 1 is currently in the conceptual phase (seeking funding to initiate planning and implementation). Some salt cedar removal and vegetation planting has occurred this year in the floodplain area just upstream of Site 1. The pipe-and-wire revetment plus vegetation projects at Sites 2 and 3 will be implemented using similar methods and materials as in Arroyo Pasajero (Viets, 2001). The length of revetment at Site 2 and Site 3 each will be approximately 200 feet. Implementation is currently being done under the guidance of the Natural Resources Conservation Service, Fresno Field Office. Monitoring of these two sites will include photo-documentation as well as collecting survey data of the plan, profile, and cross-sections in upstream, downstream, and within the stream reaches.

Site 4, in the upper watershed, is located on the Urritia property (described in Section 3.1.2). This site was evaluated during field reviews and has limited potential for application of streambank BMPs due to the high and steep streambank. The main issue of concern here relates to the stock tank and well becoming unusable as a result of the ongoing streambank erosion. The project at this site should be designed to move the well (i.e., develop a new well) farther from the streambank and, also, move the stock water tank. Because well development is not an actual erosion and sediment control BMP, installation of a new well and stock tank will not be completed under the CALFED program but, instead, under another program such as EQIP. Direct action on the streambank is not recommended as part of this project site because of the high risk of failure and continued streambank loss from erosion. Nonetheless, monitoring of this stream reach may be beneficial to further characterize the potential effects of the PG&E crossing and other land uses on stream channel change. The methods for monitoring this reach would be similar to those applied at a streambank BMP implementation site.

Site 5, also in the upper watershed, is located on the Velasquez property (described in Section 3.1.2). This site was evaluated during field reviews and also has limited potential for application of streambank BMPs due to the high and steep streambank as well as uncertainties and risk of failure from continued streambank loss from erosion. However, fencing of the streambank to prevent access by cattle, along with vegetation planting at the streambank toe, is planned for implementation at Site 5. Monitoring the effects of these BMPs will aid in future evaluations in case direct streambank protection measures are desired by the landowner.

Site 6, located on Panoche Creek just downstream from Little Panoche Road on the Hill property (Section 3.1.2), is more amenable to streambank BMPs in terms of bank height and ability to exclude cattle. However, groundwater is not present in the streambed, thus precluding vegetation as a viable part of the BMP. This site shows evidence of cattle potentially impacting local streambank stability. Therefore, fencing to exclude cattle is planned for implementation at Site 6. Monitoring the effects of this BMP will aid in future evaluations of the applicability of exclusion fencing at other streambank sites throughout the PSCW.

7.0 SUMMARY AND CONCLUSTIONS

The overall goal of the Panoche/Silver Creek Watershed benefits analysis was to provide the information necessary to understand and assess the potential economic and conservation/ecosystem benefits prior to implementing sediment control BMPs in the PSCW. In the CRMP's efforts to improve long-term watershed stewardship, the benefits gained from implementing BMPs must be considered. This study considered multiple benefits, including ecosystem health, water quality, flood control, and economic/agricultural productivity, as related to implementation of sediment control BMPs. While this is not a comprehensive benefit-cost analysis, cost estimates for BMP implementation are developed and compared with predicted benefits. This study was conducted according to the following objectives:

(1) Identify potential landowner and watershed resource needs for erosion and sediment control BMPs;

(2) Develop BMP implementation scenarios and estimate potential economic and environmental benefits to landowners and downstream interests, including agricultural producers and the City of Mendota;

(3) Estimate potential conservation benefits from BMP implementation, both locally and in downstream areas, including water and soil quality, rangeland and irrigated cropland resources, and wildlife habitat; and

(4) Develop information to support ecosystem documentation, as required for the CALFED-funded BMP testing and monitoring program.

Sediment control needs for upper watershed and lower watershed landowners and stakeholders were documented as part of this study in Section 3.0. Potential sediment control BMPs were also listed and described in Section 4.0, followed by a benefits analysis for four BMP implementation scenarios in Section 5.0. Planning and implementation requirements, including descriptions of planned BMP project sites, were also provided in Section 6.0. Results from the benefits analysis are summarized below, followed by project conclusions and recommendations.

7.1 Summary of Benefits Analysis

The benefits analysis was performed by estimating the ecological and economic value of sediment reduction, erosion control, improved water quality, and reduced flood hazard (reduced peak flows). Although numerical values could be placed on certain aspects of these benefits, others were better described qualitatively. The following four BMP scenarios were evaluated in terms of benefits to upper watershed and lower watershed landowners, stakeholders, and ecosystems: (1) erosion control structures in high runoff source areas; (2) large flood-control dam near the Panoche-Silver Creek confluence; (3) streambank protection to a significant extent; and (4) vegetative cover improvement in riparian and upland areas.

The first scenario involves application of the in-channel and flow control structure BMPs (detention facilities, or erosion control structures) in the higher sub-drainages (ephemeral streams) of the upper watershed, which is where a large volume of runoff originates because of the higher precipitation relative to the lower watershed. A total of seven such structures were assumed for this analysis. While benefits may be local, in terms of reduction of streambank erosion downstream from these structures, most benefit would be realized farther downstream in areas with much less precipitation. The technical evaluation of the first BMP scenario involved simulation of flow from seven sub-basins that were assumed to be controlled by erosion control structures. Each detention facility was assumed to impound water to a maximum depth of 20 feet with a maximum impounded surface area of 40 acres (within the non-jurisdictional dam size limitations). The extent of benefits is dependent on the magnitude and reduction of the existing peak flood discharge (2-year, 5-year, etc). The benefits of erosion control structure BMP implementation include: (1) overall reduction of peak flow in the mainstem of Panoche Creek; (2) reduction of area of flood inundation and area of sediment deposition on alluvial fan; (3) potential reduction or avoidance of damages due to overbank flooding on the alluvial fan (i.e. Belmont Avenue floods, irrigation districts impacted, etc.); (4) reduced damages during major flood events; and (5) overall savings when considering the cost of implementation vs. the reduction in potential damage in the lower watershed. This cost savings ranges from $5,000 for the 2-year event to $3.7 million for the 100-year event.

The second scenario, would involve construction of a large dam on Panoche Creek upstream from the Panoche-Silver Creek confluence. This structure would be designed to detain approximately 60 percent of the total runoff volume that normally reaches I-5. Construction of a large dam near the Panoche-Silver Creek confluence is expected to provide the same range of benefits as would implementation of erosion control structures discussed above, although the capacity of a large dam to detain flood flows would be substantially greater. The benefits of erosion control structure BMP implementation include: (1) overall reduction of peak flow in the mainstem of Panoche Creek; (2) reduction of area of flood inundation and area of sediment deposition on alluvial fan; (3) potential reduction or avoidance of damages due to overbank flooding on the alluvial fan (i.e. Belmont Avenue floods, irrigation districts impacted, etc.); and (4) reduced damages during major flood events. From the current analysis, as also supported by BOR (1981), overall savings would not occur when considering the cost of implementation vs. the reduction in potential damage in the lower watershed. The greatest benefit in terms of flood damage cost savings would exist for the 100-year event ($9.2 million), which is substantially less than the projected cost of $30 million to construct a large dam (Summers Engineering, 1998).

The third scenario would involve implementation of various streambank protection BMPs in the upper watershed. A combination of “soft” streambank BMPs and pipe-and-wire revetment are assumed for this scenario, which would not be applied where streambank heights exceed approximately 10 feet. In all areas, pipe-and-wire revetment would be installed to accelerate revegetation of the streambank areas and ensure lower erosion rates while vegetation develops. In areas of these BMP actions, fencing would also be desired to exclude cattle grazing from the areas that are recovering with new plantings and young vegetation. The total estimated cost for implementing this streambank BMP scenario is approximately $2,820 per 100 lineal feet. The potential benefit from implementing this scenario would be almost exclusively limited to the adjacent landowner (whether applied in the upper watershed or the lower watershed) and, therefore, would be most suitable for locations where property or facilities could be lost due to streambank erosion. Because these types of situations are relatively few in the upper watershed, little emphasis should be placed on this type of BMP scenario; large-scale implementation is infeasible. From a flood reduction perspective, little or no benefit would be realized to lower watershed interests from these types of actions in the upper watershed. Some benefit in sediment reduction could occur if streambank erosion could be decreased in longer streambank erosion reaches, such as near the Panoche-Silver Creek confluence. However, the feasibility (success) of implementing this full scenario is limited by the large height of streambanks in this area. However, implementation of only the pipe-and-wire revetment and plantings part of this scenario may be feasible in locations such as the Panoche-Silver Creek confluence area where streambanks are high.

The fourth scenario would involve improvement of vegetative cover in riparian and upland areas through implementation of BMPs that mainly reduce the impact of cattle grazing near streams. The annualized benefits analysis for vegetative cover improvement assumes a 20-year period, with an initial 3-year period of change in RDM and other factors. The following four management components comprise this fourth scenario at varying degrees of implementation, with each providing some level of improvement largely in the riparian areas and, to a lesser extent, in the upland areas: (1) limiting season of use; (2) designating target RDM levels; (3) riparian pasture creation; and (4) developing water systems.

While the focus of the benefits analysis for the fourth scenario was on improvement in vegetative cover for grazing and cattle carrying capacity, additional benefits would be realized including: (1) dissipation of stream energy associated with high peak flows; (2) filtering sediment, capturing bedload, and aiding in floodplain development; (3) improvement of water retention as well as groundwater recharge; and (4) development of root masses that are capable of stabilizing streambanks against erosional forces. Wildlife habitat would also be improved significantly in the PSCW. Reducing the season of use (from six to five months) could result in $45/steer in cost savings to the cattle operator, while establishing target RDM levels could increase carrying capacity and potential profit by $20.27/acre. Riparian pastures that have been managed to optimize forage productivity can also be of value to the rancher in drought conditions. Again, not only would the cattle operator benefit in terms of increased profits, but wildlife habitat would be enhanced by the additional RDM and standing crop, especially in riparian areas and upland areas near streams.

7.2 Recommendations

This benefits analysis focused on economic and ecosystem effects from implementing four BMP scenarios. Economic effects were quantified in coarse estimates and grouped broadly in terms of agricultural cropland, irrigation water districts, the City of Mendota, and cattle operators. Ecosystem effects were discussed qualitatively in terms of wildlife habitat benefits in riparian areas as well as other parts of the ecosystem. Other components that could be evaluated further, if determined to warrant the detailed analysis, include: (1) socio-economic impacts in terms of total farm revenue, farm profit, regional output, regional income, and regional employment; (2) potential benefits to recreational values and hunting resources; and (3) direct effects on agricultural cropping patterns and how trends toward salt-tolerant crops may affect BMP implementation and benefits.

Based on the results of this current study, future analyses and planning for BMP implementation should focus on: (1) erosion control structures, and (2) grazing management changes. The large dam BMP scenario should not be pursued unless new information is developed that would reduce the construction cost or elevate the damages currently estimated from existing data. The streambank BMP scenario can be pursued on a limited basis to demonstrate the potential for reducing local property loss in selected locations, although widespread implementation is not advised due to geomorphic limitations and concerns.

A different set of benefits results from implementing the erosion control structure and grazing management change BMPs. The erosion control structures would provide a large benefit in flood damage reduction in the lower watershed at relatively low cost and low risk as compared with the large dam scenario. Key issues in locating erosion control structures should be addressed, including: (1) geology, (2) soils, (3), hydrology, (4) geomorphology, (5) available materials, (6) funding for construction, and (7) other factors. Conversely, grazing management changes would provide a large benefit in terms of increased grazing capacity and land stewardship in general, especially in riparian and upland areas near streams, but would have little to no effect on reducing damages to downstream interests. Nonetheless, implementation of grazing management change is recommended in coordination with the experience of local landowners who may have discovered other techniques to utilize the resource, benefit the ecosystem, and maximize profitability.

8.0 REFERENCES

Armour, C., D. Duff, and W. Elmore, 1994. The effects of livestock grazing on Western riparian and stream ecosystems. *Fisheries* 19(9):9-12.

Bartolome, J.W., M.C. Stroud, and H.F. Heady, 1980. Influence of natural mulch on forage production on differing California annual range sites. *Journal of Range Management* 33(1): 4-8.

Bentrup, G. and J.C. Hoag, 1998. *The Practical Streambank Bioengineering Guide*. USDA, Aberdeen, ID. http://www.nhq.nrcs.usda.gov/BCS/PMC/pubs/IDPMCpubs-wet.html

Boyle Engineering Corporation, 1992. Preliminary draft letter report - development and application of hydrologic model, Panoche/Silver Creek Watershed Management Plan. Sacramento, CA. December 1992.

Brunetti, G., 2001. Personal Communication. Westlands Water District.

Bryant, J., 2001. Personal Communication. Silver Creek Drainage District and Panoche Water District.

Bureau of Land Management (BLM), 1998. *Rangeland Health Standards and Guidelines for California and Northwestern Nevada*, FINAL EIS. U.S. Department of the Interior - BLM California State Office, Sacramento, CA.

Chaney, E., W. Elmore, and W.S. Platts, 1993. *Livestock grazing on western riparian areas*. Information Center, Inc., Eagle, ID.

Corps of Engineers, U.S. Department of the Army (COE), 1994. *Office report - Cities of Firebaugh and Mendota, California, reconnaissance study hydrology*. Sacramento, CA. October 1994.

Costello, D.F. and R.S. Driscoll, 1957. *Hauling water for range cattle*. USDA leaflet 419. 6 pgs.

Cotterill, B., 2001. Personal Communication. BLM Range Conservationist, Hollister, CA Field Office.

Department of Water Resources, State of California (DWR), 1981. Precipitation depth-duration-frequency data. Sacramento, CA. December 1981. (Not seen, cited in Boyle, 1992.)

DWR, 2000. *Draft letter report from Chris Montoya to Karen Brown regarding Panoche Creek Dam Site 2 (Jones Site) analysis*.

DWR, 2001. Division of Safety of Dams, jurisdictional dam size. Internet site http://damsafety.water.ca.gov/juris-chart.htm

Elmore, W., and B. Kaufman, 1994. Riparian and watershed systems: Degradation and restoration. In: M. Vavra, W.A. Laycock, and R.D. Pieper (eds.), *Ecological implications of livestock herbivory*. Western Society of Range Management, Denver, CO:_-_.

Fisher, T., 2001. Personal Communication. Associate Environmental Planner, Caltrans.

Holechek, J.L., 1988. An approach for setting the stocking rate. *Rangelands* 10:10-14.

Kattlemann, R., and M. Embury, 1996. Riparian areas and wetlands. Pages 201-273 in: *Sierra Nevada Ecosystem Project: Final Report to Congress*, Vol. III, Chapter 5. Centers for Water and Wildland Resources, University of California, Davis.

McCullough, C., 2001. Personal Communication. Range Manager and Private Landowner in PSCW.

Meehan, B.T., 1996. Nature's chisel. *The Oregonian*, February 26, 1996.

MFG, Inc., 1998. *Panoche/Silver Creek Watershed Assessment Final Report*. Panoche/Silver Creek Watershed Coordinated Resource Management and Planning Group (CRMP) and the City of Mendota, September 1998.

Nelson, D. *et al.*, 1994. Foothill riparian. In: E. Toth, J. La Boa, D. Nelson, and R. Hermit (eds.), *Ecological Support Team Workshop Proceedings for the California Spotted Owl Environmental Impact Statement*. USDA Forest Service, Pacific Southwest Region, San Francisco, CA.

North State Resources, Inc., Stetson Engineers, Inc., Merritt Smith Consulting, and Alex Horne Associates, 1999. *Panoche Creek Corridor Project Feasibility Study – Draft Report.* Authorized by the U.S. Bureau of Reclamation. February 1999.

NRC, 1994.

Odion, D.C., T.L. Dudley, and D.M. D'Antonio, 1990. Cattle grazing in southeastern Sierran meadows: Ecosystem change and prospects for recovery. Pages 277-292 in: C.A. Hall and Doyle-Jones (eds.), *Plant biology of eastern California*. White Mountain Research Station, University of California, Los Angeles.

Pitt, M.D. and H.F. Heady, 1978. Responses of annual vegetation to temperature and rainfall patterns in northern California. *Ecology* 59(2):336-350.

Platts, W.S., and R.L. Nelson, 1985. Streamside and upland vegetation use by cattle. *Rangelands* 7:5-7.

Rosgen, D.L., 1993. Overview of rivers in the west. In: Tellman, B. *et al.* (tech. coords.), *Riparian Management: Common Threads and Shared Interests*. Western Regional Conference on River Management Strategies, Albuquerque, NM. Gen Tech Rpt. GTR-RM-226. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, CO.

Soil Conservation Service, U.S. Department of Agriculture (SCS), 1976. *Watershed investigation report, Panoche-Silver Creek Watershed, Fresno and San Benito Counties, California*. Davis, CA. April 1976.

SCS, 1994. *Inventory of resources in the Panoche/Silver Creek Watershed*. Fresno, CA. May 1994.

Strohn, E., 2000. Personal Communication. Range Manager and Private Landowner in PSCW.

Summers Engineering, Inc., 1998. *Panoche/Silver Creek Erosion and Flood Control Proposal for Mendota and Surrounding Agricultural Areas.* Prepared for City of Mendota, Panoche Creek

Coordinated Resource Management and Planning Group (CRMP), and the Silver Creek Drainage District.

USDA Economics and Statistics System, 2001. (*Livestock and Poultry Situation and Outlook* - Oklahoma City Feeder Steer Prices). http://usda.mannlib.cornell.edu.

Vallentine, 1963.

Vallentine, J.F., 1990. *Grazing Management*. Academic Press, Inc., San Diego, CA.

Viets, R., 2001. Personal Communication. Farmer and Private Landowner in Arroyo Pasajero Watershed.

TABLE 1

Predicted Panoche Creek Peak Flow Rates

Return Period (years)	Predicted Peak Flow Rates (cfs)			1-Day Volume (acre-ft)
	Range	Average	# of Studies	
100	18,050-33,500	22,310	6	13,400
50	12,300-18,600	14,130	6	8,090
25	7,740-9,550	8,510	5	4,480
10	3,330-4,100	3,750	6	1,700
5	1,510-2,100	1,810	2	643
2	291-520	410	2	83

Notes:

1) Sources: Boyle (1992) and COE (1994)
2) cfs = cubic feet per second; 1 acre-foot = 43,560 cubic feet.
3) Peak flow rate predictions for Panoche Creek are based on gaging data at USGS station #11255500, located on Panoche Creek below the confluence of Panoche and Silver Creeks

TABLE 2

Lower Watershed Estimated Damages – Existing Conditions

Return Period	Peak Flow (cfs)	Estimated Total Damages	Data Source
2-yr	410	$10,000	Assumed per Caltrans info
4-yr	1,300	$457,000	BOR (1981)
5-yr	1,810	*$713,000*	Interpolated
	2,700[1]		Provisional USGS data (2001)
10-yr	3,750	*$1,300,000*	Interpolated
15-yr	5,400	$1,800,000	BOR (1981)
25-yr	8,510	*$1,949,000*	Interpolated
30-yr	9,940	$2,018,000	Summers (1998), Fisher (2001)
50-yr	14,130	*$5,094,000*	Interpolated
100-yr	22,310	$11,100,000	Summers (1998)

Notes:

1) 2,700 cfs is the approximate threshold for significant flooding and sediment damage to cropland off of Belmont Avenue.
2) Italicized values are estimated based on linear interpolation.

TABLE 3
Potential Best Management Practices (BMPs)

Option	BMP Type	Description	Potential Effectiveness for Erosion Control	Implementation/Management	Cost	Refs
Contour furrowing	Upland Structural	• Furrows at toe of a slope or at a grade change in the slope • Provide drainage path for water to run across contour and off the slope • Shorten slope length, reduce velocity and volume of overland flow • **Materials Needed**: Conventional farm equipment	• Effective method of controlling surface erosion	• Can only be implemented in relatively small areas due to slope steepness • High maintenance requirements because of ongoing grazing and unstable soils	Low	1
Soil imprinting	Upland Structural	• Impressions in the soil surface for moisture retention and seed protection • Reduces erosion and enhances vegetative growth because of the surface storage created • Difficult to implement on steep hillslopes • **Materials Needed**: A variety of specialized equipment possible – bulldozer tracks, modified pipe, culti-packer, or sheeps-foot	• Effective method of reducing erosion and enhancing vegetative growth	• Can only be implemented in relatively small areas due to slope steepness • High maintenance requirements because of ongoing grazing and unstable soils	Low	1
Contouring	Upland Structural	• Methods include terraces, steps, rolling terrain • Shortens slope lengths on eroding slopes • Slows overland flows • Retains moisture for vegetation • Difficult to implement on steep hillslopes • **Materials Needed**: Conventional farm equipment, bulldozer, excavator	• Effective method of controlling surface erosion	• Can only be implemented in relatively small areas due to slope steepness • High maintenance requirements because of ongoing grazing and unstable soils	Moderate	1
Revegetation	Upland Structural; Riparian Structural	• Permanent, perennial cover in the form of seeded or planted native herbaceous species, shrubs, and trees • Can provide self-sustaining, zero-maintenance form of erosion control • Intended for areas that do not have high selenium or low pH problems • Improved habitat • Restoration of historic plant community in the form of native perennial grasses • COORDINATE W/ CA. NATIVE PLANT SOCIETY – CA. NATIVE GRASS SOCIETY • **Materials Needed**: Conventional seeding/planting methods; Steeper slopes could require special all-terrain equipment or hydroseeder, with associated additional costs	• Effective method of protecting banks during peak flows and filtering sediment, and restoring habitat • Would act as sediment trap downgradient of highly erosive hillslopes	• Readily implementable except in areas of steeper slopes where specialized equipment would be needed • Grazing needs to be deferred for 3 growing seasons • Long-term maintenance requirements minimal if overgrazing is curtailed	Low to Moderate	1
Soil Stabilization	Upland Structural	• Temporary measures include soil amendments or erosion blankets, application of polymer stabilizing agents • Permanent measures include rock mulch • For use in highly erosive areas • Decreases mobility of sediment from erodible hillslopes • **Materials Needed**: Specialized equipment; Hydroseeders to spray stabilizing amendment	• Effective method of reducing erosion and mobility of contaminants	• Can only be implemented in relatively small areas due to slope steepness • Maintenance requirements high, unless done in conjunction with revegetation efforts	Moderate	1
Road Improvement	Upland Structural	• Stabilization of unpaved roads and ranch roads to reduce sediment contribution • Methods include paving heavily used roads or placing gravel on more lightly used dirt roads • Could include outsloping, rolling dips, frequent water bars, etc. on natural surfaces • **Materials Needed**: Conventional road construction equipment	• Effective in controlling erosion and sediment transport by surface water, but probably not a large source of sediment	• Implementable with conventional construction equipment • Maintenamce requirements lower than present because road stability would be increased	Moderate	1

Option	BMP Type	Description	Potential Effectiveness for Erosion Control	Implementation/Management	Cost	Refs
Continued annual assessment of RDM levels	Upland Process	• Needed to monitor the success of ongoing range management relative to the objectives • Provides an iterative procedure for maintaining erosion control through prevention of overgrazing • Difficult to implement on steep hillslopes • **Materials Needed**: None	• Effective for maintaining management of range utilization	• Easily implementable • Long-term commitment to this BMP required for its success • Possible stakeholder involvement	Low	1
Definition of target levels-of-condition for levels of soil erosion	Upland Process	• Establishment of target RDM levels and acceptable range of values to account for seasonal variability • **Materials Needed**: None	• Effective for focusing range management objective on minimization of soil erosion	• Readily implementable with additional staff • Long-term commitment to this BMP required for its success • Possible stakeholder involvement	Low, if personnel available	1
Revision of RDM levels in critical areas	Upland Process	• Involves adjustments to levels in critical areas • Results in improved cover conditions • Protects endangered species • **Materials Needed:** None	• Effective method of providing improved cover in critical areas	• Readily implementable with additional staff and stakeholder involvement • Long-term commitment to this BMP required for its success	Low to Moderate	1
Implementation of a rotational grazing system	Upland Process	• Involves alternating grazing on various pastures within the season of use • Results in improved conditions in critical areas, by not allowing grazing or congregation of cattle for extended periods of time • Protects endangered species • **Materials Needed**: None	• Effective method of improving conditions in critical areas	• Readily implementable with additional staff and stakeholder involvement • Long-term commitment to this BMP required for its success	Low to Moderate	1
Establishment of a grass bank (deferred grazing)	Upland Process; Riparian Process	• Involves purchase of alternate land area by a non-profit organization • Land area can be offered to ranchers who need to maintain their herd while their impacted lands can recover • Results in reduction of erosion potential • Protects endangered species • **Materials Needed**: None	• Effective method of resting critical areas while preserving economic viability of ranching operation	• Readily implementable with public and/or private funding • Long-term commitment to this BMP required for its success	High	1
Development of a CRMP-based range management plan	Upland Process	• Involves watershed-scale cooperative program to manage grazing of private and public lands • Results in site-specific range management on public and private lands • Management decisions could be applied by public and private land owners and address critical areas of high erosion potential • Protects endangered species • **Materials Needed**: None	• Effective venue for site-specific range management on public and private lands	• Easily implementable • Long-term commitment to this BMP required for its success	Low to Moderate	1
Saltcedar control	Riparian Structural	• Removal of saltcedars and establishment of native vegetation • Contributes to streambank stabilization and trapping of sediment • Should target heavy infestation areas and areas of high habitat value • **Materials Needed**: Heavy equipment; Herbicides	• Effectiveness dependent on specific program, which could act to increase and/or re-establish riparian habitat	• Long-term maintenance involves annual monitoring • Implementation in conjunction with revegetation • Most effective if undertaken from upstream to downstream	Moderate to High	1
Reclamation of the historical floodplain	Riparian Structural	• Floodplain reclamation as part of a land retirement program • Levees would separate floodplain from agricultural cropland • Effective for reducing the current effects of flooding on agricultural land • **Materials Needed**: None	• Effective method for management of floodplains and restoring riparian habitat	• Implementable with long-range planning and budgeting • Long-term mainteneance not yet identified	High	1

Option	BMP Type	Description	Potential Effectiveness for Erosion Control	Implementation/Management	Cost	Refs
Fencing	Riparian Structural	• Establish fencing around riparian areas to control livestock access • Effective for accelerating recovery of heavily impacted riparian areas • Improves riparian habitat • **Materials Needed**: Conventional construction equipment	• Effective method of reaching desired ecological condition and tailoring grazing to specific site requirements	• Easily implementable • Annual maintenance needed for flood damage to in-stream fencing	Moderate	1
Revetment installation	Channel Bank	• Construction of revetments with natural materials, such as tree snags, or with riprap or gabions placed in stream channel • Effective for restoring channel functions, with decreased benefit in areas of continued grazing and/or ongoing natural processes • Best implemented in selected critical areas • Improves riparian and in-stream habitat • **Materials Needed**: Conventional construction equipment	• Effective method of restoring channel functions, but overall effectiveness to the system may be limited by ongoing natural processes and land use impacts	• Implementable with conventional construction in selected critical areas • Long-term maintenance requirements high because of highly dynamic nature of channels	High	1
Fiberschine	Channel Bank	• Coconut-fiber roll product that traps sediment from sloughing streambank • Placed at toe of streambank • Herbaceous wetland plants or willows planted into or behind fiberschine • Improves riparian and in-stream habitat • **Materials Needed**: Fiber rolls or biologs; 10-12 gauge wire; wood stakes; sledgehammer; 2 person minimum	• Effective method of restoring habitat, stabilizing streambank, and providing erosion control	• Implementable with conventional construction in selected critical areas • Long-term maintenance requirements high because of highly dynamic nature of channels	Moderate	2
Erosion control fabric	Channel Bank	• Tightly woven coconut fiber blanket is the most durable option for stream applications • Prevents erosion on slope until vegetation can establish and stabilize the slope • Probably best to use in combination with other techniques • Improves riparian and in-stream habitat • **Materials Needed**: Erosion control fabric; shovel; wedge-shaped wooden stakes; sledgehammer; 2 person minimum	• Effective method of restoring habitat, stabilizing streambank, and providing erosion control	• Implementable with conventional construction in selected critical areas • Long-term maintenance requirements high because of highly dynamic nature of channels	Moderate	2
Brush layering	Channel Bank	• Bundles of willow cuttings form a “terrace” that can reduce the length of slope of the streambank • Eventually, the willow cuttings sprout, take root, and stabilize the streambank • Improves riparian and in-stream habitat • **Materials Needed**: Willow cuttings; clothesline cord or wire; chainsaw or loppers (to harvest willows); shovel; 2 person minimum	• Effective method of restoring habitat, stabilizing streambank, and providing erosion control	• Implementable with conventional construction in selected critical areas • Long-term maintenance requirements high because of highly dynamic nature of channels	Low to Moderate	2
Brush mattress	Channel Bank	• A mat of willow cuttings stabilizes the slope of the streambank • Cuttings are spread in trench and along face of slope to make a mattress • Improves riparian and in-stream habitat • **Materials Needed**: Willow cuttings; clothesline cord or wire; chainsaw or loppers (to harvest willows); shovel; 10-12 gauge wire; wood stakes; 2 person minimum	• Effective method of restoring habitat, stabilizing streambank, and providing erosion control	• Implementable with conventional construction in selected critical areas • Long-term maintenance requirements high because of highly dynamic nature of channels	Low to Moderate	2
Pole plantings	Channel Bank	• Plantings revegetate the eroding streambank • Poles of willow cuttings are planted in a spacing pattern that covers high and low water levels • Improves riparian and in-stream habitat • **Materials Needed**: Willow or cottonwood cuttings; Polytwine; chainsaw or loppers (to harvest plant material); shovel; auger or planting bar; 2 person minimum	• Effective method of restoring habitat, stabilizing streambank, and providing erosion control	• Implementable with conventional construction in selected critical areas • Long-term maintenance requirements high because of highly dynamic nature of channels	Low to Moderate	2

Option	BMP Type	Description	Potential Effectiveness for Erosion Control	Implementation/Management	Cost	Refs
Post plantings	Channel Bank	• Larger diameter plantings revegetate the eroding streambank • Willow or cottonwood posts are placed in heavily eroded areas and at fluctuating water levels • Improves riparian and in-stream habitat • **Materials Needed**: Cottonwood or willow posts; metal cap (for pushing in posts); chainsaw; Stinger and backhoe; 2 person minimum	• Effective method of restoring habitat, stabilizing streambank, and providing erosion control	• Implementable with conventional construction in selected critical areas • Long-term maintenance requirements high because of highly dynamic nature of channels	Moderate	2
Brush trench	Channel Bank	• Buried willow cuttings are placed in trench along top of streambank filter runoff and alleviate piping problems • Once established, the willows stabilize the streambank • Should be used in combination with mid-bank protection methods • Improves riparian and in-stream habitat • **Materials Needed**: Willow cuttings; closthesline cord or wire; chainsaw or loppers (to harvest willow); shovel or pick-ax; 2 person minimum	• Effective method of restoring habitat, stabilizing streambank, and providing erosion control	• Implementable with conventional construction in selected critical areas • Long-term maintenance requirements high because of highly dynamic nature of channels	Low to Moderate	2
Vertical bundles	Channel Bank	• Bundles of willow cuttings are placed in vertical trenches along eroding streambank • Once established, the willows stabilize the streambank • Should be used in combination with mid-bank protection methods • Improves riparian and in-stream habitat • **Materials Needed**: Willow cuttings; clothesline cord or wire; chainsaw or loppers (to harvest willow); shovel; wood stakes; 2 person minimum	• Effective method of restoring habitat, stabilizing streambank, and providing erosion control	• Implementable with conventional construction in selected critical areas • Long-term maintenance requirements high because of highly dynamic nature of channels	Low to Moderate	2
Willow wattles	Channel Bank	• Sausage-like bundles of live cuttings tied together and inserted into trench in streambank • Once established, the willows stabilize the streambank • Improves riparian and in-stream habitat • **Materials Needed**: Willow cuttings; clothesline cord or wire; wood stakes; chainsaw or loppers (to harvest willows); shovel; 2 person minimum	• Effective method of restoring habitat, stabilizing streambank, and providing erosion control	• Implementable with conventional construction in selected critical areas • Long-term maintenance requirements high because of highly dynamic nature of channels	Low to Moderate	2
Channel reconfiguration	Channel In-stream	• Reworking of natural meanders to reduce scour, slow runoff event velocity, and enhance deposition of sediment • Re-establishment of sand and gravel bars to offer habitat and suitable growth medium for vegetation • Requires drastic disturbance in the initial work stages • Improves riparian and in-stream habitat • **Materials Needed**: Conventional construction equipment	• Effective method of restoring channel hydraulic and sediment transport function, but overall effectiveness to the system may be limited by ongoing natural processes and land use impacts	• Implementation requires in-depth investigation to determine long-term viability • Maintenance and adjustment during first several years intensive • Long-term maintenance requirements low	High	1
Temporary check dam installation	Channel In-stream	• Involves placement of straw bales or plastic fencing in channel • Could be implemented in critical areas to provide short-term erosion control and stabilization, while actions to address long-term problems are implemented • Improves riparian and in-stream habitat • **Materials Needed**: Conventional construction equipment	• Effective temporary method of short-term erosion/sedimentation control	• Readily implementable, but only a temporary (interim) measure • Maintenance requirements low to moderate	Low to Moderate	1
Construction of permanent upper watershed erosion control structures	Channel In-stream	• Development of erosion control structures • Could be placed in upper reaches of stream system where precipitation is highest • Detains storm runoff water, releasing it downstream at a slower rate • Improves riparian and in-stream habitat • **Materials Needed**: Conventional construction equipment	• Effective method of reducing peak flows and, therefore, flood flow velocities and depths and sediment yield	• Implementation requires geotechnical/feasibility investigation • If placed upstream, maintenance requirements low • If placed downstream, annual maintenance required to include sediment removal	Moderate to High	1

Option	BMP Type	Description	Potential Effectiveness for Erosion Control	Implementation/Management	Cost	Refs
Installation of small grade-control structures	Channel In-stream	• Permanent grade-control structure consists of individual steps, with reduced grade between steps • Stabilizes steep channel gradient through the reduction of the streambed slope • Sediment accumulating in structures need not be removed • Improves riparian and in-stream habitat • **Materials Needed**: Conventional construction equipment	• Effective method of stabilizing headcutting channels; unknown effect for this watershed	• Implementable with conventional construction • Long-term maintenance requirements low	Low to High	1
Construction of a large flood-control dam near confluence of Panoche/Silver Creeks	Channel In-stream	• Construct dam of jurisdictional size on Panoche Creek, just downstream of the confluence of Panoche and Silver Creeks • Provides flow control and storage capacity for a large volume of flood water and sediment • Reduced peak flow rate would result in decreased streambank erosion • **Materials Needed**: Conventional construction equipment	• Effective for control of flood flow rates and sediment transport; would become ineffective with large buildup of sediment; high O&M requirement	• Implementation requires extensive geotechnical/feasibility investigation • Operation and maintenance required to remove accumulated sediment	High	1

References:

1 MFG/WLA. 1998. Panoche/Silver Creek Watershed Assessment Final Report. Prepared for PSCW CRMP. Sept. 28, 1998.

2 Bentrup, G. and J.C. Hoag. 1998. The Practical Streambank Bioengineering Guide. USDA.

TABLE 4
Reductions in Peak Flow and Sediment Load Due to Erosion Control Structures

Return Period	Existing Peak Flow (cfs)	Peak Flow w/ 7 Erosion Control Structures (cfs)	Peak Flow Reduction w/ 7 Erosion Control Structures %	Existing Total Suspended Sediment Load[1] (tons/day)	Reduced Total Suspended Sediment Load[1] (tons/day)
2-yr	410	205	50%	88,000	30,000
5-yr	1,810	980	46%	700,000	280,000
10-yr	3,750	2,100	44%	2,000,000	1,000,000
25-yr	8,510	5,400	37%	7,000,000	3,600,000
50-yr	14,130	9,600	32%	14,900,000[2]	8,400,000[2]
100-yr	22,310	17,180	23%	29,000,000[2]	20,000,000[2]

[1] Estimates from Mass Load Rating Curve (Figure 13 North States Resources *et. al.*, 1999).
[2] Extrapolated from figure 13 best fit line ($y=10.609x^{1.4816}$).

TABLE 5
Comparison of Lower Watershed Estimated Damages with and without Erosion Control Structures

Return Period (yr)	EXISTING CONDITIONS		WITH 7 EROSION CONTROL STRUCTURES		
	Peak Flow (cfs)	Estimated Total Damages[1]	New Peak Flow (cfs)	New Total Damages	Cost Savings
2	410	$10,000	205	$5,000	$5,000
5	1,810	$713,000	980	$296,000	$417,000
10	3,750	$1,300,000	2,100	$859,000	$441,000
25	8,510	$1,949,000	5,400	$1,800,000	$149,000
50	14,130	$5,094,000	9,600	$2,002,000	$3,092,000
100	22,310	$11,100,000	17,180	$7,354,000	$3,746,000

[1] Total Damages estimated by interpolation between data points.

TABLE 6
Comparison of Lower Watershed Estimated Damages with and without Large Dam

Return Period (yr)	EXISTING CONDITIONS		WITH ONE LARGE DAM		
	Peak Flow (cfs)	Estimated Total Damages[1]	New Peak Flow (cfs)	New Total Damages	Cost Savings
2	410	$10,000	Controlled	$0	$10,000
5	1,810	$713,000	Controlled	$0	$713,000
10	3,750	$1,300,000	960	$286,000	$1,014,000
25	8,510	$1,949,000	3,750	$1,300,000	$649,000
50	14,130	$5,094,000	5,400	$1,800,000	$3,294,000
100	22,310	$11,100,000	7,400	$1,896,000	$9,204,000

[1] Total Damages estimated by interpolation between data points.

TABLE 7
BENEFIT-COST ANALYSIS: GRAZING MANAGEMENT AND STREAM RESTORATION PROGRAM

TABLE 7A
Costs for Example Restoration Program

Implementation Year	BMP Components of the Restoration Program[1]	Unit	Cost	Quantity	PV Factor	Final Cost ($)
1	Fence riparian pasture	MILE	$ 3,000.00	1.55	1.00	$ 4,650.00
1	Plant cottonwood/willows	100 LF	$ 575.00	26.40	1.00	$ 15,180.00
1	Install drip line	100 LF	$ 100.00	26.4	1.00	$ 2,640.00
1	Install Willow Wattles	100 LF	$ 851.00	14.2	1.00	$ 12,084.20
1	Reconfigure channel	100 LF	$ 7,274.00	4	1.00	$ 29,096.00
1 thru 3	Develop upland water	EACH	$ 2,500.00	4.00	0.79	$ 7,936.00
1 thru 3	Short-term AUM reduction	AUM	$ 23.85	400.00	0.80	$ 7,584.30
4 thru 20	Increase in herding work months	MO.	$ 898.82	1.00	9.82	$ 8,826.41
						$ 87,996.91

TABLE 7B
Benefits for Example Restoration Program

Benefit Year	Collective Benefits[2]	Unit	Cost	Quantity	PV Factor	Final Benefit($)
5	Emergency grazing for drought[3]	AUM	$ 23.85	100.00	0.68	$ 1,623.23
9	Emergency grazing for drought	AUM	$ 23.85	100.00	0.60	$ 1,431.48
14	Emergency grazing for drought	AUM	$ 23.85	100.00	0.34	$ 812.09
4 thru 20	Long-term AUM Increase	AUM	$ 23.85	288.00	9.82	$ 67,451.62
4 thru 20	Higher market weight[4]	CWT	$ 91.26	50.00	9.82	$ 44,808.66
						$ 116,127.08

1 Restoration of a ½-mile reach of stream, equivalent to a 100 acre rectangular riparian pasture (2640 LF) x (1650 LF) = ½ mile length x 1650 LF width

2 Collective benefits are realized from full implementation of the grazing management and stream restoration program.

3 Emergency grazing for drought is estimated for a utilization increase of 25%.

4 Higher market weight may be expected when livestock is taken off range before heat and dry conditions cause weight loss (BLM Rangeland EIS 1998, Cotterill 2001)

5 BMP = best management practice; LF = lineal feet; AUM = animal unit month; PV = present value